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The Satin Moth, *Stilpnotia salicis* (L.), in the Maritime Provinces and Observations on Its Control by Parasites and Spraying[1]

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Introduction

The satin moth, *Stilpnotia salicis* (L.), has been a pest of shade trees in the Maritime Provinces for about 25 years. Surveys of its distribution were started by the Division of Plant Protection (9) immediately following the discovery of this introduced species in 1930 and later carried out annually by members of the Fredericton Laboratory and the sub-laboratories at Debert, N.S., and Corner Brook, Newfoundland. The surveys have been accompanied by periodic collections and rearings, but only the larger and more representative of these are discussed in the present paper.

Intensive studies have been limited because of the remoteness of infestations from the Fredericton Laboratory. However, the following account of the insect and its control factors should provide a useful guide for any future work on the epidemiology of the satin moth.

Experimental spraying has been carried out in several localities, and co-operation in spraying programs has been extended to several communities. This paper describes the conditions under which chemical control is justifiable and the effectiveness of several spray formulations.

History of Distribution

The satin moth is a native of Europe and western Asia (7). It was first discovered in North America near Boston, Mass., (2, 12) and at New Westminster, B.C., (7) in 1920. The insect was first seen in the Maritime Provinces in 1930, when it was found at Sussex, St. Andrews, and the Moncton area in New Brunswick, and at Amherst and several points in Annapolis, Digby, and Yarmouth counties in Nova Scotia. It reached St. John's, Newfoundland, by 1934, Cape Breton Island and Prince Edward Island by 1935, and the Magdalen Islands by 1937. It was first reported from McAdam, N.B., in 1937, Bathurst, N.B., in 1938, Woodstock, N.B., in 1950 and Perth, N.B., in 1952. Although it is not known to occur in the northern County of Madawaska, it was taken at more northerly points in the Province of Quebec as early as 1938. By 1954 the insect covered much of the more thickly settled areas of the Atlantic Provinces. Its distribution (Figs. 1, 2) is closely associated with the planting of poplars as shade trees.

One would expect from the very widely scattered infestation that the initial introductions into the Maritime Provinces were the result of moth dispersion from the New England States. Some of the "invasion points" in Nova Scotia and New Brunswick follow very closely those of the brown-tail moth, *Nygmia phaeorrhoea* (Donov.), which Gilliatt (6) showed very conclusively was introduced from the New England States by a flight of moths.

More localized extensions may have resulted from flights of adults, or movement of larvae in air currents or on highway vehicles. Dispersion in the

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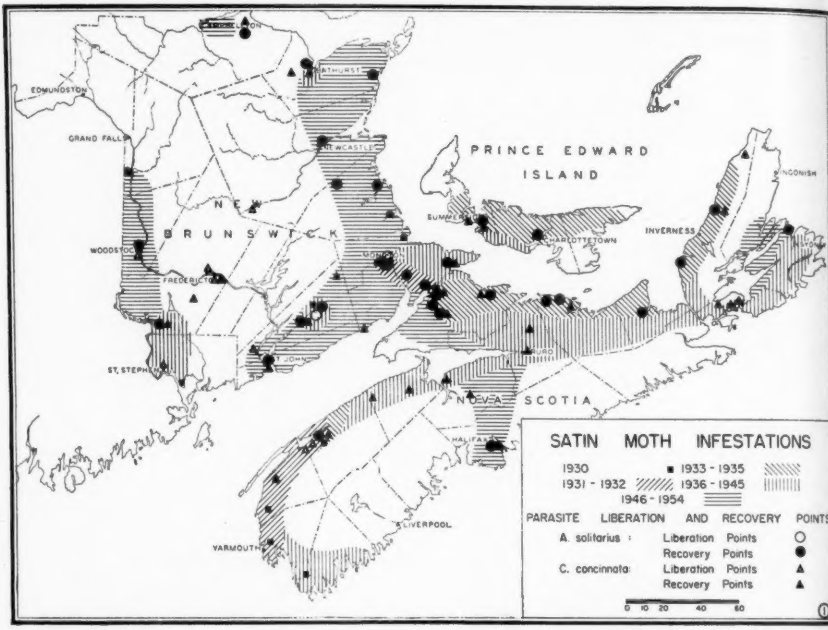
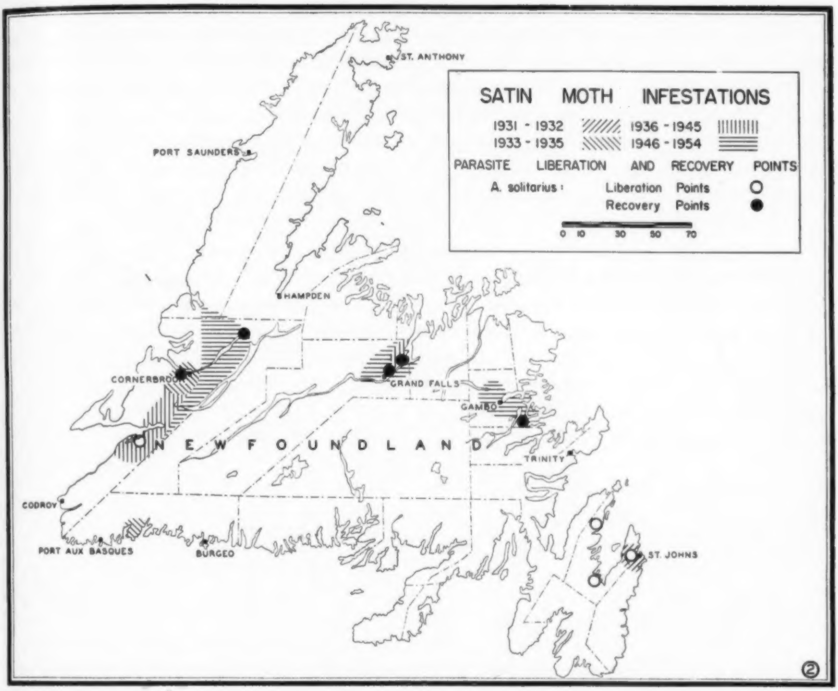


larval stage is suggested because one of its introduced parasites, *Apanteles solitarius* (Ratz.), which is specific to the satin moth and attacks the early instars, is so often present in isolated infestations. The latter are often represented by one infested tree. The possibility of the parasite adult finding these isolated and small infestations so frequently cannot be explained satisfactorily on the basis of chance alone. Considering St. Andrews and Moncton as two possible foci from which localized infestations extended, the annual estimated rate of spread northward to Perth and Bathurst was 8 and 13 miles per year, respectively. Of course the true rate of spread depends on the distribution of host trees, and its measurement is always open to doubt because of the uncertainty of the true focal point of the infestation.

The accompanying maps (Figs. 1, 2) show the approximate distribution of the satin moth over a 25-year period, but they fail to show the periodicity of distribution or attack. Annual observations at Moncton, Sussex, and Amherst, show that there have been three outbreaks since the initial infestations at these localities in 1930. These lasted 4 to 8 years for the first outbreaks and 4 to 9 years for the second. The third lasted 3 years at one location and was still active at each of the other localities in 1954. Periods between these outbreaks average 4 years, ranging from 2 to 6 years.

Host Trees and Damage

The satin moth can complete its development only on species of poplar and willow. Willows have been relatively scarce in the Maritime Provinces since the epidemic of willow blight in the early thirties, but surviving trees are occasionally attacked by the satin moth. The species of poplar most commonly attacked in this region are Carolina poplar, *Populus eugenei* Simon-Louis, and silver poplar, *P. alba* L. Balsam poplar, *P. balsamifera* L., and Lombardy poplar,



P. nigra L. var. *italica* Muench., are less frequently attacked. Although the insect is primarily a pest of planted trees, natural stands of poplar and willow have been attacked in the New England States (8) and British Columbia (7). There is only one known instance of natural stands of trembling aspen being severely attacked in the Maritime region. This was noted between Grand Falls and Bishops Falls, Newfoundland, in 1953 (4).

The trees will refoliate after complete stripping. The second crop of leaves are smaller and lighter in colour than the first crop. Repeated stripping of poplar foliage for four consecutive years may cause little tree mortality, but considerable branch-killing. The death or severe branch-killing of Carolina poplar has followed severe attacks in at least two localities, Salisbury, N.B. and Nappan, N.S. At the former locality, forty-six 30-year old trees in a hedgerow planting were almost completely defoliated in 1946 and 1947 and lightly to moderately defoliated from 1948 to 1954. By 1955 four of the trees were dead. The estimated branch mortality of the remaining trees ranged from 10 to 90 per cent and averaged 40 per cent. The history of the infestation in the Nappan area was much the same. The trees were about 25 years old and growing in a hedgerow. None of the 65 trees had been killed by defoliation to 1955 but the branch mortality ranged from 10 to 80 per cent with an average of 30 per cent.

The nuisance to property owners caused by larvae migrating from infested trees over houses has forced many communities to cut Carolina and silver poplars. Some 350 poplars were reported to have been cut in or near Moncton in 1933 because of a severe infestation, and the use of poplar as a shade tree is becoming less popular in some areas.

Life History and Habits

The life history of the satin moth varies considerably between climatic regions. Development is somewhat later in Newfoundland than in Nova Scotia or New Brunswick. The observations that follow are based on field conditions at McAdam, N.B., and insectary rearings at Fredericton.

The eggs are laid in masses of 200 or more on tree trunks, posts, buildings, or other objects. Egg mass counts on a completely defoliated, 40-foot Carolina poplar (D.B.H.–15″) showed that 73 per cent of the total 1,261 egg masses were on the stem below the crown. The remainder were in the lower crown.

Oviposition commences very soon after adult emergence, and eggs can be found in the field from about July 15 to August 15. Glendenning (7) states that the moth lays from 250 to 450 eggs, but noted that egg production was higher when the moths were reared on Lombardy poplar. Burgess (2) noted that the average egg production per female was about 500 in the New England States. In Fredericton, adults were caged individually with foliage of Carolina poplar. Only three oviposited, laying from 588 to 1061 eggs with an average of 860. Sixteen were dissected for oocyte counts. Only the mature or nearly mature eggs were counted. These averaged 305.4 ± 29.9 per adult. A comparison of the various oviposition records with the dissection group suggests that many of the immature oocytes present at eclosion develop during adult life and that fecundity cannot be accurately determined from dissections.

The incubation period is about 14 days. Hatching commences about the last of July, with the majority of the eggs hatching during the first week of August. The young larvae migrate to the foliage, which is lightly skeletonized from the feeding. After a few days of feeding the first-instar larva migrates down the tree and constructs a light web, usually in a crevice of the bark on the trunk or lower branches, and moults. After moulting, the second-instar larva migrates to the foliage and feeds for about a week, again returning to the trunk or branches to prepare a hibernaculum. The distance the larva travels from the foliage to a hibernating site is largely dependent on the roughness of the bark. The hibernaculum is similar to but spun more firmly than the moulting web. The latter is also darker because of particles of bark woven into it. The larva moults within the hibernaculum before hibernating. Hibernation commences as early as August 13, and the majority are in their overwintering webs by September 10.

The larva issues from its hibernaculum from May 3 to May 20. After a brief feeding period, the third-instar larva migrates to the branches or trunk to make a moulting web, usually from late May to mid June. All subsequent moulting generally occurs within a rolled leaf. From the fourth instar on, the entire leaf, excepting the larger veins, may be consumed. The number of larval instars has been reported as seven in the New England States (3) and British Columbia (7) and nine in Russia (14). Of 31 specimens reared individually to the adult stage at Fredericton, 11 males and 4 females had seven instars; 2 males and 4 females had eight.

The last-instar larva spins a flimsy silken cocoon on the foliage, buildings, or other sites. Pupation commences about the first of July, with the peak about July 10. Adult emergence occurs from about July 10 to August 10, with the majority emerging the last ten days of July. The emergence of males generally precedes that of females by one or two days. Males and females generally occur in almost equal numbers. A sample of adults reared in 1939 contained 786 males and 740 females.

Natural Control

Low winter temperatures, fungi, birds, and parasites are the most important natural control factors of the satin moth in the New England States (8). Glendenning (7) also recognized the importance of these agencies in British Columbia, and attached considerable importance to the overwintering mortality of the third-instar larvae. This mortality was associated with a fungus organism, *Spicaria canadensis* Vail, which may or may not have been primary. Marlatt (10) noted that hibernating larvae were affected to a high degree by two fungi, *Isaria* sp. and *Beauveria globulifera.*

High mortality of overwintering larvae has been noted in New Brunswick. The mortality tends to be very high when the minimum winter temperature falls below -30°F. Of 442 larvae collected at Woodstock, N.B., on March 22, 1955, 94 per cent were dead at the time of collection. The minimum winter temperature for the area was -40°F.

Wind is another aspect of weather that undoubtedly exerts varying degrees of control. When the foliage of the host tree is slightly disturbed, many first-instar larvae drop on threads and remain suspended for some time. They are easily dislodged from their threads, and probably many of them are dispersed long distances by wind. A few may reach new host trees, but one would expect the majority to fall on plants unsuitable for food. The young larva is hairy and buoyant, very much like that of the gypsy moth, which is known to have dispersed up to 30 miles from its source.

Since 1950, samples of diseased larvae received by the Forest Insect Survey were given to D. E. Elgee of the Fredericton Laboratory for diagnosis. There is nothing to indicate from his observations that the incidence of disease has played a very important role in destroying larvae. However, moderately high mortality was noted in 1953, when about 12 per cent of 500 larvae (instars 4 to 8) in 27 collections were diseased at the time of receipt. These showed the presence of bacterial organisms, which perhaps were secondary. Two specimens in 1952 showed evidence of a polyhedral disease, and two samples were infected with fungus organisms, one of which appeared to be a species of *Penicillium.* Mortality has always been high in insectary rearings (Table 2), but undoubtedly a good deal of this is caused by secondary infections or unsatisfactory shipping or rearing conditions.

Parasitism by native species is negligible, and is less than 1 per cent of all rearings. The primary species reared include the dipterous parasites *Achaetoneura frenchii* Will. and *Exorista mella* Wlk., and the ichneumonids, *Coccygomimus pedalis* (Cress.) and *Glypta* sp. A colony of parasites was reared from a single satin moth pupa, which was one of 8 collected as larvae at E. Bathurst in 1955. The parasites were identified as *Megaselia iroquoiana* (Mall.), a species of Phoridae. Presumably this is a primary but perhaps rare species.

Introduced Parasites

The Biological Control Unit began a program of parasite introduction against the satin moth in 1932, and four species were released from 1932 to 1942. One of these was also released as early as 1912 against the brown-tail moth, so any discussion on recoveries must include these two hosts, and others in case of polyphagous parasites. Three of the four introduced species have been recovered in the Maritime Provinces. These are *Apanteles solitarius* (Ratz.), *Compsilura concinnata* Mg., and *Meteorus versicolor* (Wesm.).

TABLE 1
Summary of Introduced Satin Moth Parasites Released in the Maritime Provinces to 1954

Species	Province	Year	Location	Number
Apanteles solitarius (Ratz)	N.B.	1933	Moncton	1,171
		1934	Sussex	41
	Nfld.	1936	St. John's	463
		1940	Brigus	45
		1940	Carbonear—Bay de Verde District	35
		1942	Sandy Point, St. George	507
Eupteromalus nidulans (Thoms.)	N.B.	1932	Moncton	2,592
		1933	Moncton	4,200
		1933	Sussex	1,945
	N.S.	1933	Amherst	2,440
Meteorus versicolor (Wesm.)	N.B.	1913	Whittier Ridge	475*
	Nfld.	1942	St. Georges	23
Compsilura concinnata (Mg.)	N.B.	1912	Fredericton	1,238*
		1912	St. Stephen	1,119*
		1913	Fredericton	1,238*
		1913	Nerepis	1,500*
		1913	St. Stephen	1,500*
		1914	Fredericton	1,500*
		1914	Harvey	2,000*
		1914	Woodstock	1,500*
		1915	Keswick	1,800*
		1932	Moncton	239
		1933	Moncton	728
		1937	Fredericton	610
	N.S.	1913	Bear River	1,500*
		1915	Annapolis Royal	1,500*
		1933	Amherst	374

*Released against the brown-tail moth, but the species also attacks the satin moth.

Apanteles solitarius (Ratz.)

History of Distribution.—This parasite was first released in the United States in 1927 (12) and several colonies were liberated in the states of Massachusetts, New Hampshire, and Washington from 1927 to 1932. Introductions were first made in Canada in 1933, when the parasite was released in British Columbia and the Maritime Provinces. The Maritime liberations (Table 1) were confined to New Brunswick and Newfoundland.

There was no evidence of the occurrence of *A. solitarius* in the Maritime Provinces prior to the 1933 liberations. About 12,000 overwintering larvae were collected at Moncton during the winter of 1930-31. Half of these were reared (Table 2) and half dissected, but there was no parasitism by *A. solitarius*. The first confirmed recovery of the parasite was on March 12, 1934, the winter following the first liberation, when 288 parasitized larvae were collected and reared (Table 2). In 1935 it was recovered at Amherst, N.S., Pugwash, N.S., Charlottetown, P.E.I., and Port Hood, N.S., indicating dispersion of 30, 50, 80, and 126 miles, respectively, in two years. Since 1935, *A. solitarius* has reached all the principal infestations in the Maritime Provinces (Figs. 1, 2).

Life History and Habits.—*A. solitarius* is a solitary endoparasite, capable of laying up to 516 eggs (12). It can reproduce by arrhenotokous parthenogenesis. Adults attack the first two instars of the satin moth from late July to early September. Overwintering of the parasite occurs in two stages, as a first-instar larva or as a prepupa in the cocoon. About 200 larvae were collected on August

TABLE 2
Parasitism of Larvae of the Satin Moth collected in NEW BRUNSWICK and NOVA SCOTIA from 1931 to 1955

Stage collected	Year	Location	No. coll.	Rearing results					Percentage** parasitized
				Host emerged	Host died	Parasitized			
						A. solitarius	*C. concinnata*	Other sp.	
Larvae I–III	1937	McAdam, N.B.	125	23	41	61	0	0	72.6
III	1931	Moncton, N.B.	6,000	?	?	0	0	0	0
	1932–33	Moncton, N.B.	1,005	?	?	0	0	0	0
	1933–34	Moncton, N.B.	1,209	18	859*	288	0	44	94.8
	1954–55	Woodstock, N.B.	442	24	418*	0	0	0	0
V–VIII	1937	McAdam, N.B.	186	51	80	0	55	0	51.9
	1937	Moncton, N.B.	164	74	64	0	26	0	28.9
	1937	Pugwash, N.S.	97	23	73	0	1	0	4.1
	1938	Moncton, N.B.	333	30	69	0	234	0	88.6
	1938	Port Elgin, N.B.	200	65	114	0	21	0	24.4
	1939	Moncton, N.B.	133	36	92	0	5	0	12.2
	1939	Sussex, N.B.	2,200	830	1,136	0	234	0	22.0
	1939	Bathurst, N.B.	499	173	316	0	11	0	6.0
Pupae	1939	Kingston, N.S.	1,100	602	339	0	159	0	20.9
	1948	Four location, N.B.	430	174	0	0	256	0	59.5
	1949	Moncton, N.B.	146	4	0	0	141	0	97.2
	1949	Salisbury	36	4	0	0	31	0	88.6

*Including those dead at time of collection
**Based on living material only.

28, 1937, and reared in a cage with a section of unpeeled wood for hibernating sites. One hundred and twenty spun hibernacula, from which 54 *A. solitarius* issued as larvae in the fall and 5 the following spring.

The fall emergence of larvae and cocoon-spinning occurs from about August 25 to October 16, and adult emergence occurs the following spring from about May 25 to late June. These attack satin moth larvae that have issued from their hibernacula, and produce a new generation of adults in about a month. The second generation adults probably live three or four weeks (12) and attack the young satin moth larvae that appear in late July. This generation may overwinter in the first larval instar or cocoon stage. There is no clear indication of a third generation in New Brunswick. The adults from the overwintering larvae emerge from about June 4 to 30 and subsequent development is similar to that of the group that overwinter as pupae.

Effectiveness.—A few counts of the populations of the satin moth and *A. solitarius* were made at McAdam in the spring of 1938. The infestation was discovered in 1937, and the nearest liberation point was in Sussex, where the parasite was released in 1934. The counts were made from 13 sample units of bark, each measuring one square foot in area. These were located on the trunk 2 to 9 feet from the ground, with five extending into the lower crown. The undisturbed hibernacula and their contents were removed from the sampling areas in the early spring. The moulting webs and contents were also removed periodically until no more could be found.

All the material was dissected. As might be expected, the satin moth population tended to be highest in the upper samples and lightest in the lower samples. The correlation between the satin moth population and distance from the ground for the series is significantly strong, with the calculated r for 9 degrees of freedom$=$1.28. There was no correlation between the *Apanteles* populations and distance from the ground, or between the percentage of parasitism and host density, although more adequate sampling might prove otherwise. This suggests that the parasite is equally effective at all levels within the range sampled or under conditions of moderate to heavy host populations. The satin moth population (parasitized and unparasitized) per sq. ft. of bark was 31.0 ± 9.4, and this was high enough to cause complete defoliation in the late instars. The corresponding population of *A. solitarius* (cocoons and larvae) was 10.1 ± 3.3, indicating a total parasitism of about 33 per cent.

Other collections of young satin moth larvae (Table 2) show that parasitism may vary considerably with the season and locality. These figures, however, include many cases of unsuccessful parasitism, where the parasite prepupae or pupae were killed by secondary parasites and other causes.

The interaction of secondary or tertiary parasites imposes limitations on the parasites' effectiveness, which are hard to measure. It is not unusual to find that the majority of the cocoons are attacked by hyperparasites or are empty (Tables 3, 4). The following parasites have been reared from cocoons of *A. solitarius* in New Brunswick: *Dibrachys cavus* (Wlkr.), *Eupelmus spongipartus* Foerst., *Eupelmella vesicularis* (Retz.), *Tetrastichus coerulescens* Ashm., *Habrocytus phycidis* Ashm., *Eurytoma* sp., possibly *appendigaster* (Swed.), *Hemiteles* sp., and *Gelis* sp. Some of these may be tertiary parasites of the satin moth, especially *Gelis* sp. *Pediobius tarsalis* (Ashm.) is perhaps a tertiary parasite (11), but rearings in New Brunswick indicate that it can develop as a secondary (or primary parasite of *A. solitarius*). In 1955 single specimens of *Alegina* sp. (not *A. apantelis*) and *Hypopteromalus inimicus* Mues. were reared

TABLE 3
Parasites Reared from Field-Collected Cocoons of *A. solitarius* at McAdam, N.B.

Season*	Year	No. collected	No. dead	*Apanteles* emerged	Parasites emerged by sp.				
					Sp. 1	Sp. 2	Sp. 3	Sp. 4	Sp. 5
Spring	1938	137	88	5	2	40	1	1	0
Early Summer	1938	102	47	3	12	28	11	0	1
Fall	1937	90	47	2	0	40	1	0	0

*Spring = May and early June.
Early summer = late June and early July.
Fall = late August and September.
Sp. 1 = *Pediobius* sp., possibly *tarsalis* (Ashm.)
Sp. 2 = *Dibrachys cavus* (Wlkr.)
Sp. 3 = *Eurytoma* sp., possibly *appendigaster* (Swed.)
Sp. 4 = *Hemiteles* sp.
Sp. 5 = *Eupelmella vesicularis* (Retz.)

from field-collected satin moth larvae. The former is definitely a hyperparasite of *A. solitarius*, but the role of *H. inimicus* was not definitely established.

The most destructive secondary parasite is *D. cavus* (Table 3). One hundred and twenty seven field-collected cocoons of *A. solitarius* that were parasitized by *D. cavus* averaged three parasites per cocoon, and one third were males. Emergence commenced about May 27. Two generations were reared in the insectary, but three or more may occur. This parasite and *E. spongipartus* reduce the effectiveness of *A. solitarius* in another way. Both species have been observed in the field and laboratory drilling holes in *Apanteles* cocoons, without laying eggs, and then feeding at the puncture. It is suspected that this type of feeding kills the contents of the cocoon, and may account for some of the high mortality noted in collections (Table 3).

Compsilura concinnata Mg.

This parasite was first introduced in the United States in 1906 (16) as part of the program of biological control of the brown-tail moth and gypsy moth, *Porthetria dispar* (L.). It was released against the former species in Nova Scotia

TABLE 4
Parasitism and Mortality of Field-Collected Cocoons of *A. solitarius*

Season*	Year	Location	No. collected	Analysis after emergence			Percentage parasitized	Percentage died from other causes
				Apanteles emerged	Secondaries emerged	Dead		
Spring	1937	Amherst	65	0	40	25	61.5	38.5
	1938	McAdam	315	11	127	177	40.3	56.2
	1955	Woodstock	302	0	0	302	0	100.0
Early summer	1937	Moncton	291	13	104	174	35.7	59.8
	1937	Amherst	47	0	23	24	48.9	51.0
	1938	Moncton	60	1	27	32	45.0	53.3
	1938	McAdam	102	3	52	47	51.0	46.1
Fall	1937	McAdam	90	2	41	47	35.5	52.2
	1937	Annapolis	17	2	2	13	11.8	76.5

*Spring = May and early June.
Early summer = late June and early July.
Fall = late August and September.

and New Brunswick from 1912 to 1915, and against the satin moth from 1932 to 1937 (Table 1). The literature contains very few references on the early establishment of this species in the Maritime Provinces. Tothill (17) recovered it from the fall webworm, at the Fredericton liberation point in 1913, which was a year after the initial release, but failed to recover it from the webworm at a number of other localities in New Brunswick or Nova Scotia during the period from 1912 to 1918. Sanders (15) noted that it had not been recovered from the brown-tail moth in Nova Scotia to 1915. Gilliatt (6) reported that it had been recovered from only one larva of the brown-tail moth to 1920 in Nova Scotia and this was taken within 2 miles of the Annapolis liberation point. It was recovered near the International Boundary at Topsfield, Maine, in 1925 and near Moosehead Lake, Maine in 1927 (16). There do not appear to be any other records of its occurrence in or near the Maritime Provinces until 1936, when it was found to be attacking the satin moth. It has since been recovered in New Brunswick, Nova Scotia, and Prince Edward Island, but it was never released in the latter Province. The known distribution of the parasite (Fig. 1) is based on recoveries from the satin moth and small collections of other hosts and therefore extends beyond the known range of the satin moth. The other hosts from which the parasite has been recovered in the Maritime Provinces are shown in Table 5. The parasite probably attacks many unrecorded hosts in the Maritimes as Schaffner (16) records about 138 host species.

The life history of *C. concinnata* in New Brunswick has been described by Tothill (17). He was uncertain as to the overwintering stage under natural conditions and the number of generations. It seems fairly certain from work in the New England States (18) that the parasite generally hibernates as larvae within the pupae of certain Lepidoptera, which serve as alternate hosts. Of the 13 host species recorded in Table 5, the parasite overwintered successfully in the pupae of only two species, *L. fiscellaria* and *H. textor*. The former species, however, overwinters in the egg stage, and this record of the parasite overwintering within the pupa of *L. fiscellaria* may be exceptional. The usual habit of the parasite overwintering in host pupae would explain the failure of the parasite to overwinter successfully in the satin moth, which hibernates in the larval stage.

Insectary rearing of field-collected larvae in 1939 gave some evidence of the possible number of generations and habits in the Atlantic Provinces. The larvae were collected from three localities in New Brunswick and Nova Scotia from July 4 to July 12. The parasite adults from this material totalled 1,520, of which 780 were males and 740 females. Superparasitism was common, with three maggots per host larva in 6 per cent of the rearings, and two per host in 31 per cent of the rearings. The remaining 63 per cent produced only one maggot per host. The adults emerged from July 12 to August 16, with the mean date being July 26. The emergence of a few parasites from other hosts (Table 5) makes an interesting comparison. Those that were collected from July 9 to August 15 produced 41 adults of *C. concinnata*, which emerged from July 21 to September 14, the mean date of emergence being August 18. From those that were collected from August 21 to September 18, three parasite adults emerged in the fall and ten overwintered in host pupae. These records suggest that one complete generation develops in the satin moth, with a second and partial third developing in alternate hosts.

The effectiveness of the parasite is largely dependent on the abundance of its hibernating hosts, as demonstrated by Webber and Schaffner (18) in their studies on parasitism of the gypsy moth and brown-tail moth. Under favourable conditions, *C. concinnata* can parasitize over 90 per cent of late-instar larvae of

TABLE 5
Summary of Insects other than *S. salicis* from which *C. concinnata* has been reared in the Maritime Provinces

Family	Host species	Overwintering stage of host	Species of plant host collected from	No. of collections	No. of hosts reared	No. of parasites emerged
Nymphalidae	*Nymphalis antiopa* (L.)	adult	balsam poplar	1	11	6
			balsam poplar	1	18	4
			willow	1	37	11
Saturniidae	*Antheraea polyphemus* (Cram.)	pupa	?	1	1	1
Citheroniidae	*Anisota rubicunda* (Fabr.)	pupa	soft maple	1	1	1
Arctiidae	*Hyphantria textor* Harr.	pupa	white spruce	2	2	2
			alder	1	20(?)	1
Phalaenidae	*Acronicta fragilis* Gn.	pupa	birch	1	2	1
	Acronicta obliniata A. & S.	pupa	peony	1	7	7
	Graptolitha sp.	?	white spruce	1	1	1
Notodontidae	*Datana ministra* (Drury)	pupa	apple	1	1	1
Liparidae	*Hemerocampa leucostigma* A. & S.	pupa	tamarack	1	50	2
			balsam fir	2	29	3
			mixed	4	90	4
	Nygmia phaeorrhoea (Donov.) (6, 17)*	larva	apple	1	?	2
Geometridae	*Nematocampa limbata* Haw.	egg (?)	yellow birch	1	1	1
	Lambdina fiscellaria (Guen.)	egg	red spruce	1	3	1
			mixed	4	117	4
Undetermined	Undetermined	(?)	apple	1	1	1

*Tothill (17); Gilliatt (6).

the satin moth (Table 2). In some years the parasite appears to be very ineffective. Dissections of 180 satin moth larvae collected near Bathurst on June 24, 1955, showed only 1.1 per cent parasitism by this species.

Meteorus versicolor (Wesm.)

This parasite was introduced in America primarily as a parasite of the brown-tail and gypsy moths. Schaffner (16) noted that it was not recovered beyond the limits of the brown-tail moth infestation and concluded that it may be dependent on that host for hibernation in the New England States.

One colony of this parasite was released against the brown-tail moth in the Maritime Provinces and another against the satin moth (Table 1). The dates of these releases were 1913 and 1942. Only two specimens are known to have been recovered in the Maritime region. These were reared from 15 larvae of the satin moth collected at McAdam, N.B. on June 30, 1952. Evidently the parasite is of little value in controlling the satin moth in the Maritime Provinces.

Eupteromalus nidulans (Thoms.)

This has been introduced as a parasite of the brown-tail moth and satin moth in the New England States (13) and the Maritime Provinces (Table 1). Parasitism of overwintering satin moth larvae was as high as 58 per cent in one locality (1), and averaged 9 per cent during the period 1926 to 1929 at points in the New England States (13).

Although an early report of the Fredericton Laboratory indicated that this species was recovered at Moncton in 1933, confirmation is lacking. Evidently it was confused with *A. solitarius*, and there are no definite records of its establishment in the Maritime Provinces.

Chemical Control

There are many cases of satin moth outbreaks in the Maritime Provinces ending without the aid of spraying. There is evidence that parasites and weather, and possibly disease organisms are largely responsible for controlling these outbreaks. Occasionally outbreaks do not terminate until many branches are killed. When infected trees are close to houses, owners frequently insist on spraying to rid them of the nuisance of migrating caterpillars. Several tests have been made of various spray formulations and procedures, which can be considered as spring spraying and summer spraying.

Spring Spraying

Collins and Hood (5) have shown that the satin moth can be satisfactorily controlled for at least two years, and sometimes longer, with one application of lead arsenate. The effectiveness of one application was confirmed by a fairly large-scale spraying operation at McAdam on June 13, 1938. The equipment was a solid stream shade tree sprayer, with a capacity of 50 U.S. gallons per minute and a pressure of 400 pounds at the pump. The formulation used in one zone consisted of 5 pounds of lead arsenate and 3 pounds of pyrethrum to 100 Imperial gallons of water. Stickers were added to the formulation for spraying two zones of the Town. These were goulac at the rate of 3 pounds and fish oil at the rate of one pint to 100 gallons of spray material. The pyrethrum was in the form of a fine powder and guaranteed to contain not less than 0.8 per cent pyrethrins. Some 225 trees, mostly Carolina poplars, were sprayed in one day by a crew consisting of a foreman, driver, nozzle-man, and two hose-men. The trees ranged from 15 to 55 feet in height and averaged 30 feet. The dosage averaged 12 gallons per tree. The decision to spray in this case was unavoidably delayed, but normally should be done when the leaves are first fully developed. Tests were made for the presence of arsenious oxide on sprayed foliage a month

after spraying and showed that the amount of this chemical was decidedly higher where fish oil was used as a sticker. However, regardless of the formulation, no living larvae could be found on the trees one day after spraying, nor did noticeable defoliation recur until 1945.

Six laboratory tests were made to determine the residual effect of DDT on treated foliage and bark. Both 50 per cent DDT water suspension and DDT emulsion were used at rates ranging from 1 to 10 pounds of actual DDT to 100 Imperial gallons of spray material. About 100 half-grown larvae were used in each test, with an equal number in each of two checks. The larvae were obliged to eat sprayed foliage in one series or crawl over 18 inches of sprayed bark in the other. Applications of 1 or 2 pounds of actual DDT to 100 gallons of water applied to the foliage caused complete mortality within 3 to 5 days. An application of 10 pounds of actual DDT to 100 gallons of water applied to the bark caused complete mortality in 6 days. There was no mortality in the checks. Because of its residual effect, DDT formulations should be more satisfactory than lead arsenate for spray applications. Although adequate field trials are lacking, preliminary tests indicate that DDT water suspension or emulsion used as a foliage spray at the rate of 2 pounds of actual DDT to 100 gallons of water, with 1 pint of linseed oil, should give satisfactory control. The effectiveness will also depend on the degree of coverage. Orchard spraying equipment of the solid stream type is not adequate for spring spraying if the trees are large. Small hydraulic sprayers are not adequate for trees over 40 feet tall.

Summer Spraying

The chief advantage of summer spraying is that it can be done with a small power sprayer, or even a hand sprayer. The object is to treat the rough bark of the trunk and lower branches. The young larvae are killed as they crawl from the egg masses, after hatching, to the foliage. The timing is more important than with spring spraying. It should coincide with the period of maximum hatching, about August 5 to 10 in central New Brunswick.

Summer spraying was tested at three localities in 1946, 1947, and 1955. Eighty Carolina and silver poplars ranging from 30 to 50 feet in height were treated. The spray was applied with a small power sprayer, having a capacity of 4 gallons per minute at a pressure of 300 pounds per square inch. The trunks and lower branches were treated to heights of 15 to 30 feet, depending on the distribution of rough bark. Both 50 per cent DDT water suspension and DDT emulsion, were used at the rate of 5 pounds of actual DDT to 100 gallons of spray material, with one pint of raw linseed oil added as a sticker. A few unsprayed trees were left for checks. Sampling units were established for each formulation and at each locality. These totalled 15 including checks. The sample unit was one square foot of bark at eye level, and counts of hibernacula on these units were made about mid-September. No larvae could be found on any of the sample units on the sprayed trees, whereas 4 counts on the check trees averaged 71 larvae per square foot. The sprayed trees showed a trace of feeding by the young larvae in the fall but in the following spring there was no evidence of larvae or defoliation. In contrast, defoliation of the untreated trees the year following spraying was moderate to severe. It is evident that both DDT water suspension and DDT emulsion can give excellent results at a concentration as low as 5 pounds of actual DDT per 100 Imperial gallons of spray material, with one pint of raw linseed oil added as a sticker.

Summary

The satin moth is a European insect that was first reported in the Maritime Provinces of Canada in 1930. The insect subsequently spread throughout most

of the settled areas where planted poplar trees are used extensively as shade trees. Three outbreaks occurred at three localities during the past 25 years. These lasted 4 to 9 years, with periods between outbreaks averaging 4 years.

The principal climatic factor controlling rate of increase is low winter temperature. Many of the hibernating larvae are killed when minimum temperatures fall below -30°F. Of the biotic factors native parasites and disease organisms offer slight control value, but high parasitism by two introduced species of parasites was noted in some areas. These parasites are a braconid, *Apanteles solitarius* (Ratz.), and a tachinid, *Compsilura concinnata* Mg. A third introduced species, *Meteorus versicolor* (Wesm) was also recovered. The effectiveness of *A. solitarius* is sometimes adversely affected by the action of secondary parasites, especially *Dibrachys cavus* (Wlkr.), and *C. concinnata* apparently is dependent on the abundance of alternate hosts for overwintering.

The insect can be controlled easily by spraying in the spring about the time the leaves are fully developed or in early August before hatching is at its peak. An advantage of summer spraying is that it is only necessary to treat the trunk and lower branches, the young larvae being killed by the direct and residual effect of DDT during migration over the bark surface. Shade trees were thoroughly sprayed in a town in 1938, and the insect did not reappear in outbreak numbers until 1945. Spray formulations for spring and summer spraying are given.

Acknowledgments

Acknowledgment is made to Dr. R. E. Balch and Mr. L. J. Simpson for some of the early records and interest in the study. Appreciation is also expressed to Mr. G. L. Walley, Dr. O. Peck, and other members of Insect Systematics and Biological Control Unit, Science Service, Ottawa for many of the determinations of parasites, and to Dr. H. C. Coppel for checking the list of parasite liberations.

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The North American Species of *Diathrausta* Lederer (Lepidoptera: Pyralidae)[1]

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Dyar (1913) listed *Diathrausta reconditalis* (Walker) as a "form" of the South American *D. nerinalis* (Walker) and described as new the "form" *harlequinalis* from Arizona. From the context it is evident that in that paper Dyar used "form" as equivalent to geographic race, and the form names he proposed there can accordingly be treated as valid trinomina. Haimbach (1915), apparently in ignorance of Dyar's paper, described *Diathrausta montana* from Colorado. This was sunk by Barnes and McDunnough (1917) as a synonym of *harlequinalis*. Barnes and McDunnough listed *harlequinalis* as a geographical race of *reconditalis*, but did not follow Dyar in uniting these with *nerinalis*.

Series in the Canadian National Collection show that two distinct species of *Diathrausta* occur in the Ottawa region and elsewhere in the northeast. One of these is evidently *D. reconditalis*, the other is a larger species, agreeing structurally and in general features of maculation with *harlequinalis*. The latter species breaks up into at least four subspecies in North America. The material available to me of tropical forms is inadequate, but none of it (from Mexico, Costa Rica, Ecuador or Brazil) seems conspecific with either *harlequinalis* or *reconditalis*. My present impression is that all of the exotic forms discussed by Dyar are specifically different from the North American species, and that the exotic forms themselves include more than one species. Though the name *Triplodaula* Meyrick, with type *stagmatopa* Meyrick is available, I am unable to separate the forms of this group generically from *D. profundalis* Lederer, the type species of *Diathrausta*, and I accordingly sink *Triplodaula* to *Diathrausta*. *Diathrausta* is of course misplaced in the Nymphulinae. Its true position is in the Pyraustinae, probably near to *Desmia* and *Anageshna*.

Diathrausta daeckealis Haimbach is a nymphuline, identical with *Nymphula broweri* Heinrich, (new synonymy). Although it is not a true *Nymphula*, I leave *daeckealis=broweri* in that genus in order not to anticipate Lange's revision of the North American nymphuline genera.

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Key to the North American Species of *Diathrausta*

1. Expanse 16 mm. or less, postmedial line obsolescent, without obvious orange tints .... *reconditalis* Walker

   Expanse over 17 mm., or with broad, obviously orange-tinted postmedial line and basal markings .... *harlequinalis* Dyar

Diathrausta reconditalis (Walker)

Figs. 1, 3

Hymenia reconditalis Walker, 1859: 943.
Aediodes minualis Walker, 1865: 1297.
Diathrausta octomaculalis Fernald, 1887: 127.
Diathrausta reconditalis, Fernald, 1902: 397.
Diathrausta nerinalis, form *reconditalis*, Dyar, 1913: 100.

This is a small species, averaging about 15 mm. in expanse; the cell-spot of the fore wing is much reduced, the spots beyond and behind the cell less so; the postmedial line is obsolescent and without orange tints. The male genitalia show a small but apparently constant difference from the following species: the spine arising from the sacculus just ventrad of the base of the clasper is much wider and less strongly acute in *reconditalis* than in *harlequinalis*.

Type localities:—New York (*reconditalis*); North America (*minualis*); Pennsylvania, New York and Ontario (*octomaculalis*).

D. reconditalis is a northeastern species, having been recorded from New York, New Jersey, Pennsylvania and Ontario. In addition to material from the above states and province, I have seen specimens from Fontana, N.C., and from Norway Bay, Que.

Diathrausta harlequinalis Dyar, new status

Figs. 2, 4-7

Diathrausta nerinalis, form *harlequinalis* Dyar, 1913: 100.

This species has a larger cell-spot and broader postmedial lines than *reconditalis*; the northern forms are appreciably larger than *reconditalis* and the southern ones are conspicuously marked with orange.

There are four subspecies in the material before me.

Diathrausta harlequinalis harlequinalis Dyar

Fig. 4

Diathrausta nerinalis, form *harlequinalis* Dyar, 1913: 100 (in part).
Diathrausta reconditalis harlequinalis Barnes and McDunnough, 1917: 136 (in part).

Expanse 16-20 mm. Fore wing with definite orange or orange-tinted subbasal and antemedial lines, fore and hind wings both with definite and nearly complete postmedial line, orange or strongly orange-tinted, at least on fore wing. Orange tints more strongly developed in female than in male.

Type locality: Tehuacan, Mexico.

Material examined:—33 specimens, from the following localities:

Arizona: Madera Canyon, Santa Rita Mts.; Huachuca Mts.; Sabino Basin, Santa Catalina Mts.; Comobabi Mts.; Redington; Paradise.

New Mexico: Frijoles Canyon.

Texas: Palo Pinto Co.

Diathrausta harlequinalis montana Haimbach, new status

Fig. 5

Diathrausta montana Haimbach, 1915: 323, Pl. XII, Fig. 6.
Diathrausta reconditalis harlequinalis, Barnes and McDunnough, 1917: 136 (in part).

Expanse 19-23 mm. Fore wing with basal markings obscure and both wings with postmedial line much less strongly orange-tinted than in *harlequinalis*.

This subspecies seems quite distinct from *harlequinalis;* in fact it is closer to the northeastern subspecies.

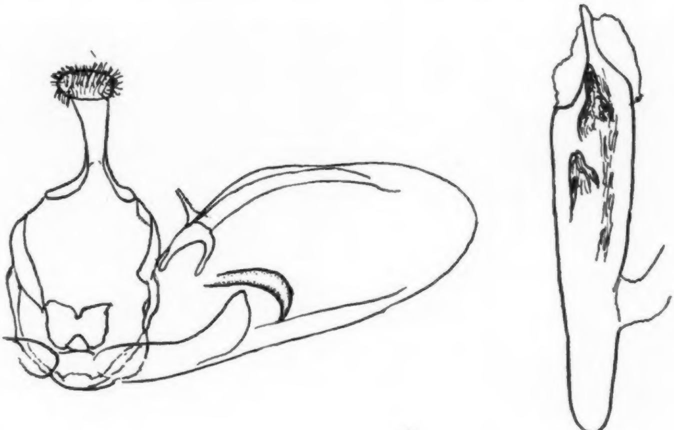
Type locality: Chimney Gulch, Golden, Colo.

Material examined:—7 specimens, from the following localities in Colorado: Strontia Springs; South Park; Larimer Co.; Jim Creek, near Boulder.

Diathrausta harlequinalis amaura, new subspecies

Figs. 2, 6

Expanse 18-22 mm. Markings much as in *montana,* but with the postmedial line of both wings narrower, usually almost obsolete on posterior half of fore wing.



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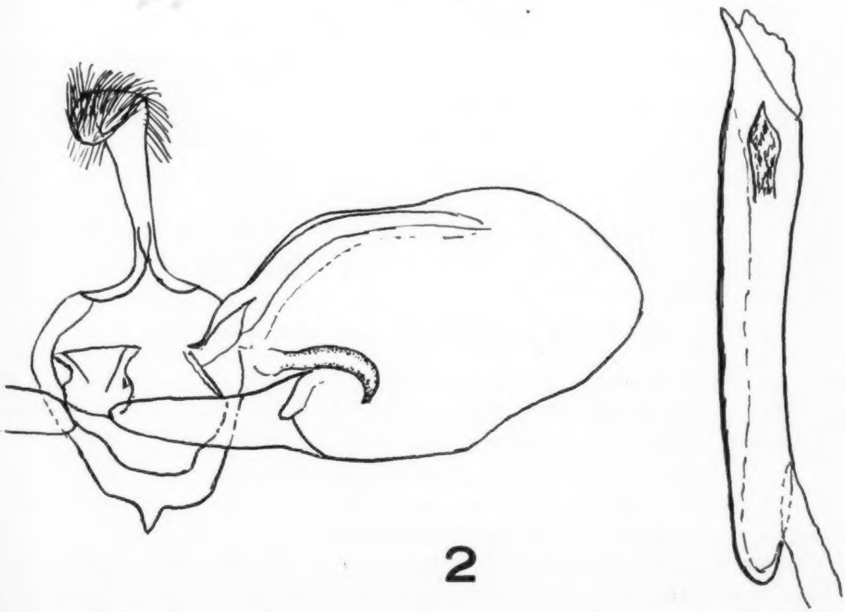

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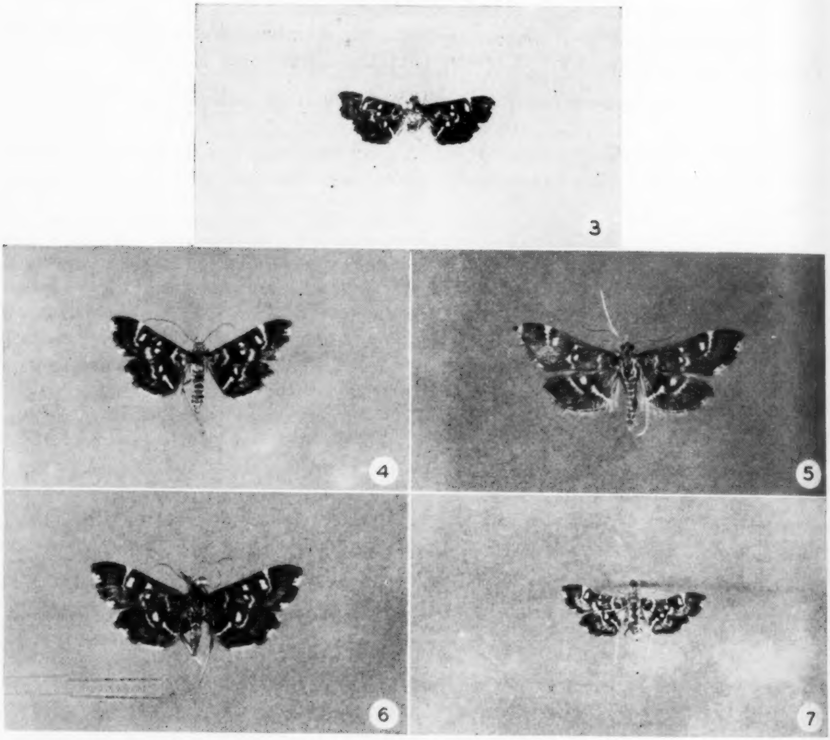
Figs. 1, 2. Male genitalia of *Diathrausta* spp.: 1, *D. reconditalis* (Walker); 2, *D. harlequinalis amaura* Munroe.



Figs. 3-7. *Diathrausta* spp.: 3, *D. reconditalis* (Walker); 4, *D. harlequinalis harlequinalis* Dyar; 5, *D. harlequinalis montana* Haimbach; 6, *D. harlequinalis amaura* Munroe, paratype; 7, *D. harlequinalis lauta* Munroe, holotype.

Holotype, male, allotype, female, and six male, three female paratypes, Norway Bay, Que., July, G. A. Hobbs and E. G. Lester, No. 6310, in the C.N.C. In the Carnegie Museum, Pittsburgh, two paratypes, Kennebunkport, Me., August; in the American Museum of Natural History, New York, one paratype, Manchester, Mass.

Diathrausta harlequinalis lauta, new subspecies

Fig. 7

Expanse: 15 mm. (male probably larger). Cell-spot of fore wing reduced. Transverse lines orange; whole basal area and much of subterminal area of both wings and conspicuous patches on median area of fore wing bright orange.

In the absence of males, the taxonomic position of this subspecies is perhaps a little doubtful, but the broad postmedial band and extensive orange colour suggest very strongly that the present association is correct.

Holotype, female, and one female paratype, Archbold Biological Station, Lake Placid, Fla., July 15-31, 1948, A. B. Klots, in the American Museum of Natural History, New York. One female paratype with the same data, No. 6311, in the C.N.C.

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Influence of Host Movement on Selection of Hosts by *Drino bohemica* Mesn. (Diptera: Tachinidae) as Determined in an Olfactometer[1]

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Two, or possibly three, types of stimuli that may influence host selection by entomophagous insects are produced by movements of the host or the prey. Movement may provide visual or tactile stimuli. Vibration caused by host movement may stimulate some species.

Tactile stimuli are produced by a host if it moves when touched by a parasite and are usually provided by a host that is enclosed in a case or a cocoon. Ullyett (1936), working with *Dahlbominus fuscipennis* (Zett.), and Williams (1951) and Thorpe and Jones (1937), working with *Idechthis canescens* (Grav.), found tactile stimuli an important factor in host selection, but Simmonds (1943) and Thompson and Parker (1927) concluded it was of little importance in *I. canescens* and *Melittobia acasta* Walk. respectively. Movement of potential prey upon contact stimulates attack by foraging ants (Vowels, 1955). Tactile stimuli produced by movement of the host may indicate an unsuitable host to the egg parasite *Trichogramma evanescens* Westw. (Salt, 1938).

Visual stimulii are produced by the movement of exposed hosts or prey. It is the principal stimulus by which the bee-hunting digger wasp *Philanthus triangulum* (Fabr.) locates its host (Tinbergen, 1951, p. 47). Cleptoparasites of wasps, such as *Senotainia trilineata* (V.d.W.) (Krombein, 1936; Reinhard, 1929; Ristich, 1953), *S. rubriventris* Macq. (Krombein, 1955), and *Nysson bellus* Cress. (Evans *et al.*, 1954), locate wasps with prey or wasps' burrows by observing the wasps' movements. Visual stimuli are important to the praying mantid *Sphodromantis guttata* (Thunb.) (Williams and Buxton, 1916) and to dragonflies (Gaffron, 1934).

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Little is known of the influence of vibration caused by movement of host or prey on the responses of entomophagous insects. When stimulated by vibration, aggregations of larvae of the cattle tick, *Boophilus annulatus* (Say) (Krigsman, 1937), and a sheep tick, *Ixodes ricinus* (L.) (Lees, 1948) break up and the larvae assume the questing position, or move around questing. Wilkinson (1953) found that larvae of *Boophilus microplus* (Can.) responded to vibration, but doubted that this stimulus was of much value in the field.

In studies on the roles of the olfactory and chemotactile senses in behaviour of *Drino bohemica* Mesn. (Monteith, 1955), there were indications that the movements of the host larvae influenced their selection by this parasite. This is a report on whether the greater attractiveness of the more active host larvae was due to the stronger olfactory and chemotactic stimuli they produce or to visual stimuli.

Methods

The degree of influence of each factor that determines host preferences of *D. bohemica* is modified by interaction between these factors (Monteith, 1955). To measure the influence of movement of the host it was necessary to eliminate the effect of all other factors. This was accomplished with an olfactometer, described in a previous paper (Monteith, 1955).

The movements of a host were simulated by suspending a small, brown contour feather in the lumen of the left arm of the Y-tube (Fig. 1). It was suspended on a fine, white nylon thread and did not touch the sides of the tube. The irregularity and arc of movement were determined by the way that the vane of the feather was trimmed on either side of its shaft and by the rate of flow of the air. The feather was made to move slowly with a slight wobble. A motionless feather did not attract the parasites.

An olfactory stimulus was required to induce response to movement of the simulated host. This was provided by placing larvae of *Neodiprion lecontei* (Fitch) in a Dreschel gas-washing bottle (Monteith, 1955) and directing a flow of air over them. This current of air then carried the odour of the larvae into both arms of the Y-tube. There was no bias in selection of the two arms when the odour was passed through them in the absence of the feather.

Preliminary tests showed the necessity of placing a second feather farther up the same arm of the Y-tube. Flies attracted to the single feather during the tests congregated near the mouth of the tube, where their movements caused some individuals to enter the opposite arm. The second feather was suspended two inches farther up the tube. It attracted flies away from the first feather and the mouth of the tube after they had found that the first feather was not a host.

Three series of ten tests each were conducted, 15 females being used in each test. In each test some of the females did not respond.

Influence of Movement

The parasites were definitely attracted by the moving feathers. The total numbers of parasites entering the arms of the Y-tube during the three series of tests were:—

Series	1	2	3	Total
Arm with feathers	67 (64.3%)	69 (69.7%)	72 (66.6%)	208 (66.8%)
Arm without feathers	37	30	36	103

The number of flies that entered the arm with the feathers was approximately twice the number that entered the other arm. The chi-square test showed the difference to be highly significant ($P < .005$).

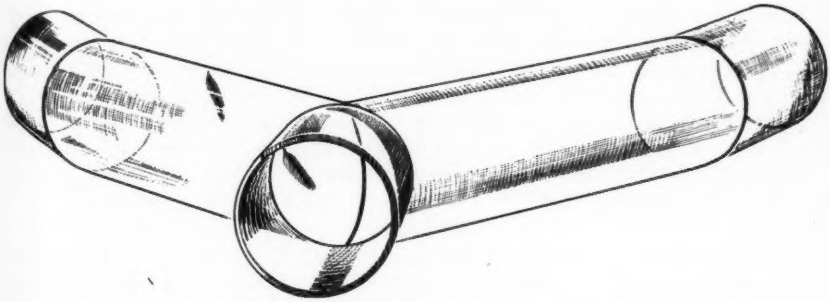

Fig. 1. View from base of Y-tube of olfactometer, showing positions of feathers.

A test of the homogeneity of the groups of flies used in the three series, by the Brant-Snedecor method, showed no significant difference between the responses of the flies in these groups (P>.32).

Discussion

The parasites were attracted by the moving feathers. Their behaviour on approaching the feathers was similar to that when approaching sawfly larvae. They rotated their antennae and moved forward a few steps at a time, pausing to rub their front legs together and stroke their ovipositors with their legs. Many alighted on the feathers and a few probed them with their ovipositors. When only olfactory stimuli were present in the olfactometer, some parasites extruded their ovipositors but no probing occurred. Movement of an object in the presence of the odour of a host was definitely a strong stimulus since the parasites were attracted to, and in some cases induced to probe, an object as different from their hosts as a feather. The visual stimulus provided *D. bohemica* by movement of its hosts was therefore different from the tactile stimulus provided by the hosts of *D. fuscipennis* (Ullyett, 1936) and *I. canescens* (Williams, 1951; Thorpe and Jones, 1937).

The stimulus provided *D. bohemica* by movement of the host is effective only if the olfactory senses are already stimulated. This differs from the order in which these stimuli act on the bee-hunting digger wasp *P. triangulum* (Tinbergen, 1951). The wasp must be stimulated by movement of an object about the size of a bee and approach the moving object before the odour induces the wasp to seize or reject it. Visual stimuli supplied by larval movement, in the presence of the odour of a host, attracts *D. bohemica* to its host. On the other hand, visual stimuli produced by wasp movements do not lead *Senotainia trilineata*, or other members of this sarcophagid genus, directly to their host but to the wasp burrow, where the host is found (Reinhard, 1929; Krombein, 1936 and 1955). Therefore, in the chain of stimuli that guide a parasite or a predator to an acceptable host, the visual stimulus is effective on *D. bohemica* at a place different from that for *P. triangulum*, and serves a function different from that in species of *Senotainia*.

Movement of sawfly larvae would make one species more attractive than another if both occurred on the same food plant and one moved more readily than the other when disturbed by the parasite. Within the species healthy larvae in the later instars would be selected most frequently, as these move more freely

and are more disturbed by the proximity of parasites (or an observer) than are larvae of the earlier instars.

The degree of influence of host movement on *D. bohemica* under field conditions would be modified by other factors. It has been shown (Monteith, 1955) that olfactory and chemotactic stimuli from the food plant of the host and from the host itself influence host selection by *D. bohemica* and that each of these stimuli modifies the effect of the others. Similarly, these stimuli would modify the effect of host movement.

Summary

The movement of feathers trimmed to resemble host larvae was a strong visual stimulus to *D. bohemica* provided that the parasite had already been stimulated by the odour of a host. Larval movement was simulated by suspending the feathers in the air stream in one arm of a Y-tube type of olfactometer in which the same host odour was passed through both arms. The response by the parasite to the moving feathers was very pronounced, but the influence of host movement would be modified by other factors in the field. The differences in the effect of host movement on this tachinid parasite and on some clepto-parasitic sarcophagids, hunting wasps, and hymenopterous parasites are discussed.

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History of the Hemlock Looper, *Lambdina fiscellaria fiscellaria* (Guen.), (Lepidoptera: Geometridae) in Newfoundland, and Notes on Its Biology[1]

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Introduction

The hemlock looper, *Lambdina fiscellaria fiscellaria* (Guen.), has been an important forest pest in Newfoundland for many years. Outbreaks have been reported from widely separated parts of the Island and in most cases the mortality of balsam fir, *Abies balsamea* (L.) Mill, has been high.

An investigation of the biology of the insect was commenced in 1950 at Lake St. George where two separate infestations had appeared in 1949. These infestations died out in 1951 and only limited information was obtained on some aspects of the investigation. As there is little prospect of continuing field studies in the near future, the results to date are being reported.

The external morphology of all stages was studied to determine if specimens from Newfoundland were conspecific with those collected on the mainland, in the Maritime Provinces, and in Quebec and Ontario. Although there is a difference in the number of larval instars between Newfoundland and mainland material, no consistent morphological differences have been found and the species are considered identical. Only the historical and biological aspects are included in the present paper.

History

Information on early hemlock looper oubreaks in Newfoundland is very limited. Available evidence suggests that four periods of outbreaks have occurred since 1912 (Fig. 1). The first was reported by Swaine (10), who described attacks that killed many square miles of balsam fir on the Port au Port Peninsula, on the coast below Bonne Bay, Deer Lake, and near Badger, from 1912 to 1915. He also reported severe outbreaks at a number of points on the Avalon Peninsula, particularly near St. John's, between 1920 and 1925. From 1930 to 1935 extensive stands of balsam fir were killed in St. Barbe District near River of Ponds, and Ten Mile Lake (1). It is probable that in other areas during those years similar outbreaks occurred of which we have now no definite record.

Since 1947, 12 independent outbreaks have occurred in widely separated localities, causing mortality of balsam fir in all cases. Eight of these, located near the Anguille Mountains, Lake St. George, Bonne Bay, Parson's Pond, St. Paul's Inlet, Lake Kepenkeck, Portland Creek, and River of Ponds, ranged from about 5 acres to square mile in area. The remaining four were much larger, and are described as follows:

Bay d'Espoir.—This extensive outbreak was first reported in 1947 (7) and investigated the following year. The principal infestation covered about 32 square miles. Two smaller infestations of from 8 to 10 acres each occurred in the vicinity (3). The outbreak terminated in 1949. Practically all the killed timber has been salvaged.

Thwart Island.—An outbreak covering an area of about 5 square miles on the eastern part of the Island and a few isolated patches on the nearby mainland were observed in 1948 (3). High larval mortality from disease occurred in 1949 and in 1950 the outbreak subsided. A salvage operation has been conducted in the area.

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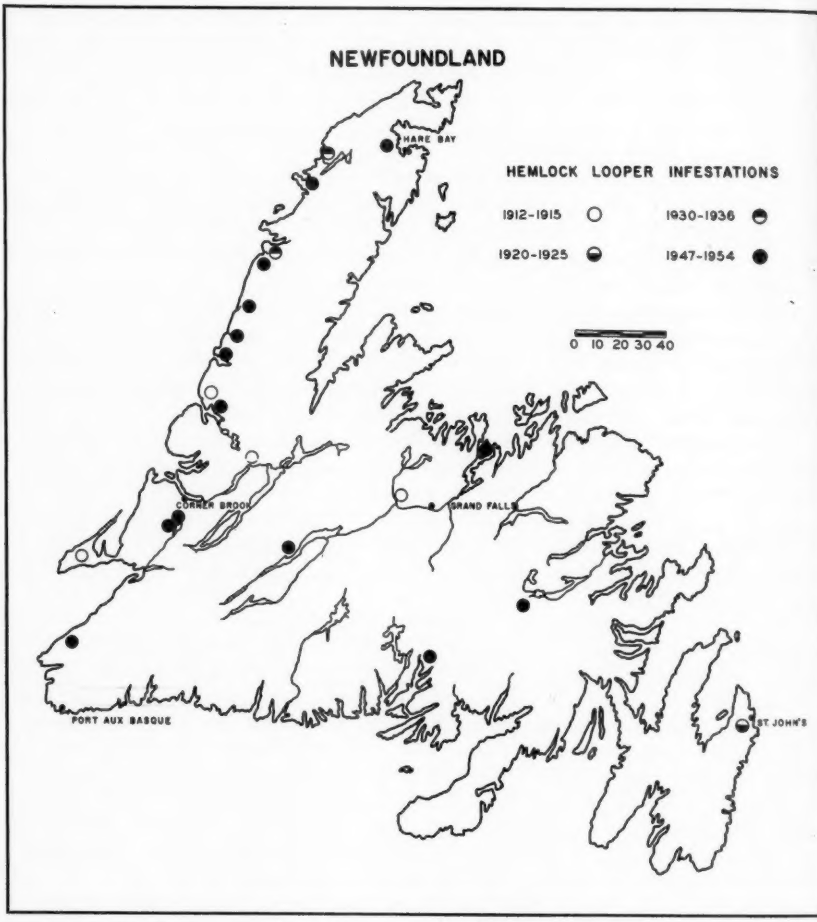

Fig. 1. Distribution of hemlock looper outbreaks in Newfoundland during the four periods of severe attack since 1912.

St. John Bay.—An area of 20 square miles was defoliated in 1949. An aerial survey in 1952 showed that the outbreak had terminated (4). A severe infestation of the black-headed budworm, *Acleris variana* (Fern.), was reported from this area one year before the looper attack began. Because of the difficulty of moving timber from this locality, salvage has not been considered practical.

Hare Bay.—This is the most severe looper outbreak ever recorded in Newfoundland. It developed very rapidly. In 1952, the loss of new foliage averaged about 15 to 20 per cent. In 1953, 37 square miles were infested and the trees were 60 to 90 per cent defoliated. In 1954, almost 50 square miles were severely defoliated. Mortality of balsam fir to date has been estimated at 300,000 cords. It is expected that from 50 to 70 per cent of the dead timber can be salvaged within the next four years. This outbreak subsided in 1955, except in a small area where 25 per cent of current growth was eaten.

The above outbreaks all resulted in mortality of balsam fir but others have terminated without killing trees. At Spruce Brook a moderate to severe attack, 2 to 3 square miles in area, occurred in 1949 and 1950. Defoliation of balsam fir was estimated at 50 per cent of the current year's growth and 25 per cent of the old foliage in 1950, but was negligible in 1951. Natural control factors, the most important of which was a larval disease, caused the outbreak to collapse before trees were killed. A moderate outbreak of a few acres was observed on the west shore of Red Indian Lake about 30 miles from Millertown in 1949. Loss of new foliage was estimated at 50 to 75 per cent (7). Observations in 1953 showed that the outbreak had terminated without any mortality of balsam fir.

The concentration of hemlock looper outbreaks near the coast (Fig. 1), although suggesting a climatic influence is probably due more to the nature of distribution of mature balsam fir stands. The proportion of mature balsam fir is generally higher in coastal regions especially in western and northern Newfoundland, whereas, in the eastern and central areas black spruce, *Picea mariana* (Mill.) B.S.P., is the more common tree species.

Life History and Habits

Egg

Eggs are usually laid singly, but sometimes in groups of two or three, on the moss and lichens on the tree trunk, under old bark scales or in the mossy covering of stumps and logs. They are always affixed to the site in such a manner that both poles remain free.

The looper overwinters in the egg stage. Field observations and sampling of egg and larval stages in 1950 and 1951 showed that the hatching period extended from about June 6 to June 30. Eggs laid in exposed sites hatched first, those laid on the understory, or on moss or other plants growing in shaded locations, were the last to hatch. Several hundred eggs laid in oviposition cages and kept in the insectary hatched within a period of three days.

Larva

Fifteen larvae were reared individually from the egg and all had four instars. This is one less than reported by de Gryse (5) in Ontario. Measurements of head widths of field collected specimens fell within four rather distinct groups in which the per cent error between observed and calculated widths was quite low when "Dyar's law" was applied (Table 1). However, on application of the linear growth principle demonstrated by Ghent (6) for sawfly larvae, the per cent error was much higher, indicating that width increment is exponential rather than linear.

TABLE 1
Head Width Measurements of Larvae of *L. fiscellaria fiscellaria* (Guen.) Collected in the Field

	I Instar	II Instar	III Instar	IV Instar
No. measured	140	101	131	149
Range	.37–43	.60–.72	1.00–1.213	1.65–2.05
Average Width in mm.	.399	.666	1.166	1.867
Average ratio of increase = 1.673				
Calc. widths (Dyar's Rule)	.399	.668	1.114	1.951
Per cent error		0.3	4.4	4.5
Calc. widths (Linear Regression)	0.29	0.77	1.26	1.76
Per cent error	25.6	14.2	8.6	5.3

The total larval period, as determined by 15 individual rearings, ranged from 43 to 55 days and averaged 49 days. The mean number of days spent in each instar was 14.1, 9.5, 9.7, and 15.6 respectively. Data on larval development in the field were obtained from periodic collections. The earliest first-, second-, third-, and fourth-instar larvae were found in the field on June 12, June 22, July 1 and July 14, respectively (Fig. 2). No larvae were seen after August 18. There was a considerable overlapping of instars and all four have been found at the same time.

Feeding is done openly. It is rather inconspicuous in the first two instars. Third- and fourth-instar larvae feed wastefully, rarely consuming a needle entirely, and on severely-infested trees practically every needle may be damaged. These needles dry out and turn brown, and eventually drop to the ground. Browning of the foliage first becomes noticeable about the middle of July.

During the eclosion period larvae were observed on a wide range of plants, having emerged from eggs laid on or near these plants. Some experiments were conducted to determine what plant species were most suitable as food. Only plants on which larvae had been observed in the field were used. These experiments showed that first-instar larvae cannot survive when restricted to the following diets: 'old' needles of either balsam fir or white spruce, *Picea glauca* (Moench) Voss., sphagnum moss, leaves of speckled alder, *Alnus rugosa* (Du Roi) Spreng.; American mountain ash, *Sorbus americana* Marsh.; raspberry, *Rubus idaeua* L.; and bunchberry, *Cornus canadensis* L. Some feeding occurred on the last four species. One specimen that fed on raspberry and two that fed on bunchberry moulted to the second instar. They were abnormally small and died soon after moulting. First-instar larvae that had been fed new foliage of balsam fir or spruce, or leaves of birch, *Betula papyrifera* Marsh., or maple, *Acer rubrum* L. and *Acer spicatum* Lam., throughout the larval period were reared successfully to pupation. All second-instar specimens fed old foliage of spruce died, and only 3 of 20 supplied with old foliage of balsam fir pupated. Third- and fourth-instar larvae were reared to the pupal stage on old foliage of balsam fir and white spruce.

Cannibalism occurred in all cases where larvae were given unacceptable diets. First-instar larvae were unable to survive more than four days without food, many of them dying on the second and third day. It is clear that young foliage of balsam fir, spruce, birch, or maple is requisite to the survival of early instars, but older larvae can survive on old foliage of these trees.

All authors who have investigated the looper have made special mention of the wandering habits of larvae. In the first two instars, movement was not often apparent after a feeding site had been found. First-instar larvae have been observed crawling up tree trunks, apparently moving from hatching sites in search of food. In the third and fourth instars movement became very conspicuous, and there seemed to be a continuous inter and intra-tree migration. All instars drop to lower branches of the same tree, to other trees, or to the ground by means of silken threads. Those reaching the ground ascend the nearest tree regardless of size or species. Larval movement appeared to be intensified on bright days but on rainy days larvae were often seen hanging motionless from the branches on very short threads. Some or most regain the branch by climbing back up the thread using mouth-parts and pro-thoracic legs.

Observations were made on the responses of larvae to light by means of a chamber constructed from a cardboard carton having a glass jar fitted in one end. Ten first-instar larvae placed in the carton all moved to the light after four hours. When the experiment was repeated with balsam fir foliage in the

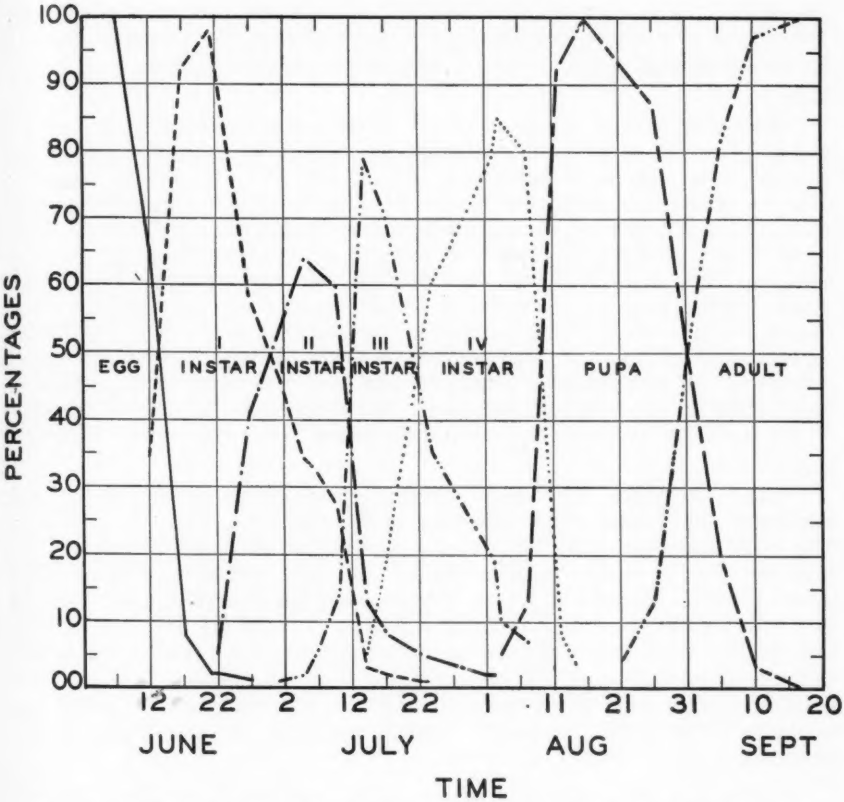

Fig. 2. Field development of *L. fiscellaria fiscellaria* (Guen.) at Lake St. George, Newfoundland.

darkened section, six larvae crawled to the light after four hours. After nine hours the chamber was opened and the remaining larvae were found feeding on new foliage. When the ten larvae were allowed to become established on new balsam fir shoots before the experiment, there was no movement to the light in less than an hour. Similar results were obtained when the experiments were repeated with second- and third-instar larvae. After larvae approached the prepupal stage, they did not move to the light. Of five larvae placed in the glass jar, four crawled to the dark compartment. The one remaining had reached the prepupal phase of development.

These experiments are only preliminary but they suggest an explanation for larval migratory behaviour. The first three instars react positively to light. This reaction is intensified in starved larvae, and enables them to reach suitable feeding sites at branch tips. When a food supply is found the response is either weakened or the photic stimulus is replaced by some other stimulus. Crowding at the branch tips forces some larvae to drop. As the larvae grow larger the crowding becomes more pronounced, and more larvae drop from the branches. The photopositive reaction tends to cause those on the ground to climb the

nearest tree. Those on the branches crawl towards the periphery of the tree. Thus there is a continuous movement. Just prior to the prepupal phase, a negative photo-taxis causes larvae to seek darkened pupation sites.

Pupa

Following a brief prepupal period larvae transform into typical obtect pupae. The first pupae were collected on August 2. Larvae reared in the insectary from eggs began pupating as early as July 14. The maximum number of pupae occurred in the field on August 16 (Fig. 2). The duration of the pupal period as determined by 20 individual rearings in the insectary, ranged from 20 to 23 days, averaging 22 days for both males and females. Preferred pupation sites were dry, decayed stumps, bark crevices, and among lichens on the tree trunk. Pupae were sometimes found on the forest floor, generally not more than 6 inches from a tree or stump; a few were found on the branches in accumulations of frass and dead needles. A study of pupal distribution on the tree carried out by cutting ten balsam fir trees into 4-foot sections and examining each section for pupae showed that 90 per cent of the pupae on the tree occurred on the stem, and of these 62 per cent were found below the crown (Table 2).

Adult

Adult emergence from field-collected pupae started on August 21 and continued until September 17. Moths were observed in the field two days later. The mean emergence date for males preceded that of females by four days apparently due to earlier pupation. Male moths were seen in the field five days before females. Females in screen cages, outside the insectary, lived from 10 to 17 days, males from 8 to 10 days, averaging 14.3 and 9.4 days respectively. One female was seen in the field as late as October 30. Two females fed diluted corn syrup lived 23 days. When the adult feeds, the extended antennae are usually in a state of rapid vibration. The proboscis is completely extended and its tip is immersed in the liquid. Feeding does not last longer than a few seconds at a time.

During the day moths were usually found in sheltered locations although some males have been observed flying on warm days. Male moths are capable of more active flight than females, and field and insectary observations have shown that fully gravid females are very sluggish and are able to fly only a short distance at a time. Generally both sexes were quiescent in the morning

TABLE 2

Distribution of *L. fiscellaria fiscellaria* (Guen.) Pupae on the Stems of Ten Balsam Fir Trees by 4-Foot Sections, Spruce Brook, Newfoundland. Trees Averaged 7″ at B. H.

Section No. from base	No. observations	Mean	Percentage pupae by sections
1	10	31.8	23.2
2	10	19.7	14.3
3	10	17.8	12.0
4	10	17.1	12.2
5	10	11.9	7.7
6	10	11.9	7.5
7	10	7.2	4.8
8	10	8.2	5.7
9	10	8.2	5.3
10	10	6.9	4.8
11	9	2.8	2.1
12	2	.4	.4

Table 3
Fecundity Studies of *L. fiscellaria fiscellaria* (Guen.)
Adults in 1950 and 1951 — Lake St. George, Newfoundland

No. of adults reared	Stage collected	Food supplied	Eggs laid		Total eggs and oocytes	
			No.	Mean	No.	Mean
87	Instar IV & pupae	Balsam fir	5,121	58.8	5,658	65.0
11	Egg	Balsam fir	749	68.1	801	72.8
15	Egg	White spruce	1,106	73.7	1,212	80.8
6	Egg	White birch	392	65.3	420	70.0
24	Egg	Maple	1,618	67.4	1,728	72.0

and early afternoon, becoming active in the late afternoon and evening. Mating was observed in only one instance, shortly after emergence of the female. The male and female remained *in coitu* for about five minutes.

Of 1,000 adults reared from field-collected larvae and pupae in 1950, 55.1 per cent were females. In material reared from eggs laid in oviposition cages 32.6 per cent of 110 adults were females. De Gryse (5) found that 10.8 per cent of field-collected specimens were females, while in reared material 32.4 per cent were females. This discrepancy in sex ratios may in part result from some of de Gryse's collections of adults being made at the beginning of the emergence period before emergence of females had reached its peak. Sex ratios may also change with the stage of the outbreak but this possibility has not been investigated. Reared females had a pre-oviposition period of from three to five days.

Studies of fecundity were made with females collected in the late larval and pupal stages and placed in screen sleeve cages pulled over branches of balsam fir trees. Each cage and branch was examined for eggs after the death of the female, and the remaining oocytes were determined by dissection. The number of eggs and oocytes per female ranged from 39 to 106 in 1950 and from 47 to 122 in 1951, averaging 58.8 for the two years (Table 3). De Gryse (5) found that the number of eggs per female averaged 100.3, the range being 41 to 148. The difference may have been due to differences in infestation level and feeding conditions.

Information on the effect of diet on fecundity is limited, as only a few specimens were reared from the egg on different kinds of foliage (Table 3). There was very little variation, whether females were reared on new foliage of balsam fir or leaves of maple. Specimens reared on new shoots of white spruce had a slightly higher egg count than those on other kinds of foliage (Table 3).

Natural Control

Parasites

Thirteen species of parasites have been reared in Newfoundland by the Forest Insect Survey (Table 4). The most common were *Aoplus velox* (Cress.) and *Apanteles* sp. nr. *flavovariatus* (Mues.). *A. velox* (Cress.) was, with one exception, obtained only from pupal collections. In 1950 it parasitized 32.2 per cent of 557 pupae collected. The parasite was not reared in 1951 when the looper population in the study areas was at a low level and only eight pupae were collected.

Apanteles sp. nr. *flavovariatus* (Mues.) lays eggs in second-instar larvae. The parasite larva issues from the dead fourth-instar host larva. The cocoon is

TABLE 4
Parasites of *L. fiscellaria fiscellaria* (Guen.)
Reared in Newfoundland

Species	Stage of host		Adult emergence period	Years reared
	Larva issued from	Adult issued from		
Diptera, Tachinidae				
Anetia eufitchiae Tns.	Pupa		9/10–10/8	1949
Madremyia saundersii Will.	Larva		8/12–9/7	1944, 45, 48, 51
Phryxe pecosensis Tns.	Pupa		8/27–9/27	1947–50
Hymenoptera, Ichneumonidae				
Aoplus velox (Cress.)		Pupa	8/26–9/24	1947, 49, 50
Apechthis ontario (Cress.)		Pupa	9/6–9/23	1947, 49
Mastrus aciculatus (Prov.)	Pupa		Summer	1947
Phaeogenes gaspesianus (Prov.)		Pupa	8/15	1946
Pimpla aquilonius (Cress.)		Pupa	9/16–9/30	1947
Pimpla pedalis (Cress.)		Pupa	9/15–9/19	1947
Apanteles sp. nr. *flavovariatus* (Mues.)	Larva		Summer	
Rogas sp.	Larva		8/28–9/3	
Hymenoptera, Scelionidae				
Telenomus dalmani (Ratz.)	Egg		Summer	1950–51

small and white, and is attached to the twig or needles of balsam fir. Only a few specimens were collected in 1950 but in 1951, 30 per cent of 173 larvae collected were parasitized by this species.

Several colonies of the parasite *Winthemia occidentis* Reinhard were introduced from British Columbia by the Dominion Parasite Laboratory, Belleville, Ontario, and liberated in Newfoundland from 1949 to 1951. No recoveries have been recorded although a few specimens tentatively determined in the field as *W. occidentis* were collected in 1951. The parasite larvae emerged from pupal cases of the host but failed to overwinter and could not be positively identified.

Predators

No attempt was made to assess the value of predators in natural control. Pentatomids, syrphids, and spiders were noted in collections, but none have been observed feeding on larvae. The following birds were noted in the infested areas: the Newfoundland black-capped chickadee, *Parus atricapillus bartletti* (Aldrich and Nutt); the Newfoundland boreal chickadee, *Parus hudsonicus rabbittsi* (Burleigh and Peters); the northeastern olive-backed thrush, *Hylocichla ustulata clarescens* (Burleigh and Peters); the yellow-bellied flycatcher, *Epidonax flaviventris* (Baird and Baird); the eastern song sparrow, *Melospiza melodia melodia* (Wilson); the white-throated sparrow, *Zonotrichia albicollis* (Omelin). The latter was observed eating adult loopers.

Disease

A virus extract obtained from dead hemlock loopers collected near Sault Ste. Marie (2) was introduced into infested areas at Bay d'Espoir and Gander Lake in 1948 (3). The occurrence of diseased specimens in the field was first reported from Thwart Island in 1949 (8). In 1950, Sheppard (9) reported that most of the larvae collected at Bonne Bay, St. Paul's Inlet and Parson's Pond, were diseased and many were dead. Considerable looper mortality from a wilt disease also occurred in the Lake St. George outbreaks, as shown in Table 5, but

TABLE 5
Field Mortality of Third- and Fourth-Instar Larvae and Pupae of *L. fiscellaria fiscellaria* (Guen.) in 1950

Locality	Date	Total	No. collected/ 100 sq. ft. foliage	Percentage dead
Lake St. George	Aug. 2	202	56.7	71.2
Lake St. George	Aug. 3	92	50.7	50.0
Spruce Brook	Aug. 4	98	22.2	35.3
Lake St. George	Aug. 4	196	52.3	34.0
Lake St. George	Aug. 7	145	49.4	30.3
Spruce Brook	Aug. 8	132	31.4	34.8
Spruce Brook	Aug. 12	130	30.5	25.0
Lake St. George	Aug. 14	63	35.4	28.0
Spruce Brook	Aug. 15	96	32.0	20.2
Spruce Brook	Aug. 18	93	26.4	13.8

the pathogen is not known. It will be observed from the Table that the percentages of dead larvae declined after the first collection. This apparent reduction in mortality probably resulted from dried cadavers being lost through the action of wind and rain. Actual field mortality was undoubtedly closer to that shown for the first date and probably exceeded 70 per cent. All outbreaks from which disease was reported collapsed in 1950.

Mortality from disease has been observed only in third- and fourth-instar larvae and pupae. The first diseased specimens were seen in the field on August 2 in 1950. Dead larvae were flaccid, and generally suspended from the needles by their ventral and anal prolegs, although occasionally they were stretched full length on a twig or leaf. Some specimens became covered with white mould shortly after death. The disease is probably native to Newfoundland as it is unlikely that the extract introduced in 1948 could have produced such immediate and widespread results. There has been no noticeable recurrence of mortality from disease since 1950, although all accessible outbreaks have been carefully checked.

Starvation

Starvation plays a part in terminating outbreaks in areas where severe defoliation of balsam fir has occurred. In one area investigated, large numbers of recently-hatched larvae were observed crawling up the trunks of completely defoliated balsam fir trees. These trees did not produce new foliage and no larvae survived except on birch trees. No doubt high mortality from starvation also occurs in the first instar when eggs are laid at a distance from preferred food plants.

Causes of Collapse of Outbreaks

The study was not intensive enough to determine the part played by the various control factors in the collapse of outbreaks. Sampling has indicated percentages of parasitism seldom in excess of 30 per cent, but the methods used were likely to result in underestimates. In some instances the percentage of larval and pupal mortality from disease probably combined with starvation has been sufficiently high to be considered the major cause of collapse. This was evidently the case at Lake St. George. However, in the Hare Bay outbreaks there was no evidence of disease and limited sampling did not indicate an unduly high percentage of parasitism. The major factor appeared to be starvation.

TABLE 6
Description of Stands at the Epicentre and Periphery of Severe Outbreaks 1950–1953

Location	Percentage of stand by stems			Stand age in years	D.B.H. in inches	No. trees per acre
	bF	S	wB			
Epicentre (100 per cent mortality balsam fir and spruce)						
Anguille Mtns.	92.8	2.0	5.2	70–80	3–4	890
					5–8	763
					9	25
Lake St. George	89.5	1.3	9.7	75–80	3–4	604
					5–8	832
					9	60
Hare Bay	82.8	10.7	6.5	76–218	3–4	101
					5–8	233
					9	371
Epicentre (no mortality)						
Spruce Brook	85.5	9.0	5.5	55–65	3–4	314
					5–8	474
					9	179
Periphery (no mortality)						
Lake St. George	66.5	28.0	5.5	55–60	3–4	216
					5–8	276
					9	72
Hare Bay	61.1	34.5	4.4	81–119	3–4	243
					5–8	342
					9	209

Stand Conditions That Favour Outbreaks

All severe outbreaks have originated in stands in which mature or overmature balsam fir predominated. Although balsam fir is the preferred host, white spruce growing with balsam fir has been killed and under population pressure other species are attacked, including black spruce, larch, maple, and birch.

Because of the inaccessibility of many outbreaks, studies on stand composition have been limited and a much more intensive study of the problem is required. Cruise lines were run in the epicentre of four outbreaks, and for comparison in the periphery of two where defoliation was light. All trees were tallied by 1-inch diameter classes above 3-inch D.B.H. (Table 6). Complete mortality occurred in the epicentres of all these outbreaks, except Spruce Brook where the attack terminated and the trees recovered. These studies indicated that all the severe attacks commenced in stands containing over 70 per cent balsam fir. An increase in the spruce content of a stand seems to have resulted in a corresponding decrease in susceptibility to attack. De Gryse (5) found that in Ontario pure or almost pure stands of hemlock over 80 years old were most susceptible. Watson (11) reported that outbreaks in Quebec occurred where balsam fir was the predominant species.

Annual radial growth measurements were made for the last 25 years on cores taken at breast height in each area cruised. Four cores were taken at cardinal points from each of ten balsam fir trees from 40 to 60 feet in height, and the average growth for each tree was recorded as shown in Figure 3. Radial growth has been extremely slow in the Anguille Mountain and Hare Bay areas. It has been somewhat faster at Spruce Brook and Lake St. George. A decline in growth began in all areas several years prior to attack by the looper suggesting

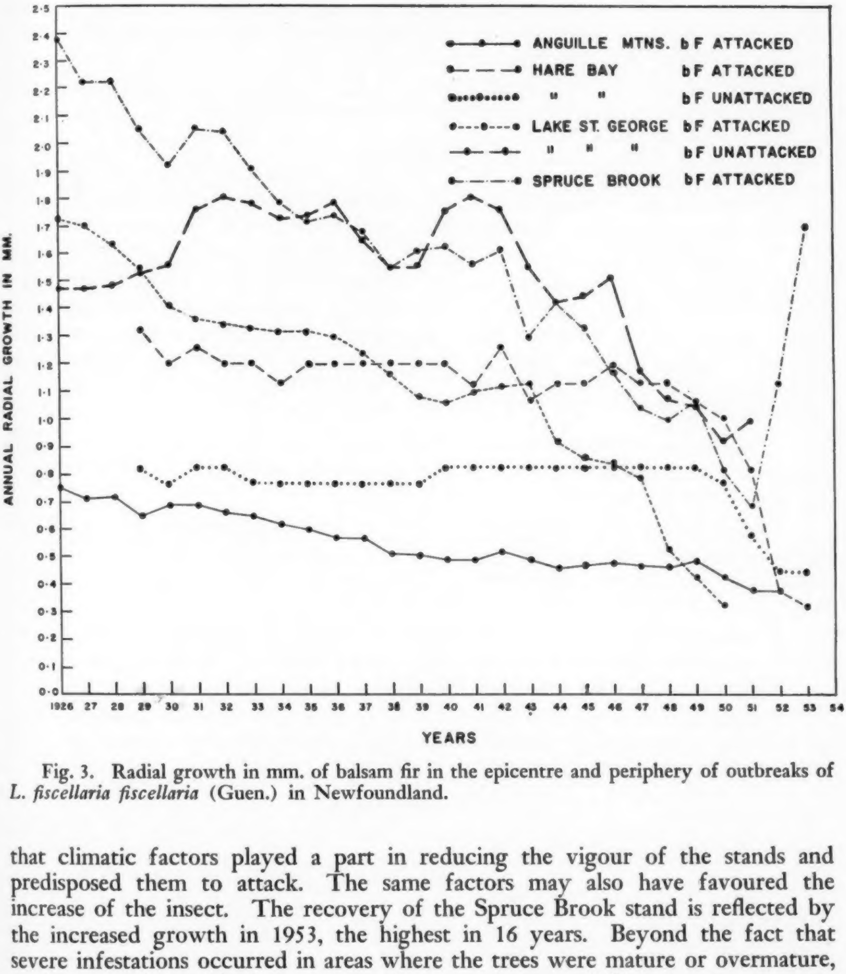

Fig. 3. Radial growth in mm. of balsam fir in the epicentre and periphery of outbreaks of *L. fiscellaria fiscellaria* (Guen.) in Newfoundland.

that climatic factors played a part in reducing the vigour of the stands and predisposed them to attack. The same factors may also have favoured the increase of the insect. The recovery of the Spruce Brook stand is reflected by the increased growth in 1953, the highest in 16 years. Beyond the fact that severe infestations occurred in areas where the trees were mature or overmature, a distinct relationship between stand age and susceptibility is not apparent. Possibly stand composition, vigour, and age should be considered jointly when determining the factors which influence the development of outbreaks.

Localized Nature of Outbreaks

A striking characteristic of looper outbreaks has been their localized nature. The boundary of the severely-infested areas is generally quite distinct and the resulting patches of almost completely dead timber are bordered by virtually uninjured stands often of the same composition. This is particularly noticeable when small outbreaks are scattered through a relatively uninfested forest. The simultaneous occurrence of many of these outbreaks suggests that although related in origin they develop independently of each other. They may originate from moth flights drifting in from another infested area or from locally developing populations. Female moths, however, are poor flyers and have rarely been seen at heights more than fifteen feet from the ground, a factor which probably

has considerable influence in circumscribing outbreaks after they develop. The rapid development of outbreaks is probably related to this limited spread. They appear suddenly and may strip and kill many of the trees in the first year of noticeable attack. In the second year most of the trees in the infested area may be killed and most outbreaks have subsided within three years.

Summary

The hemlock looper has been the most destructive forest defoliator in Newfoundland for many years. Four periods of severe attack have been recorded since 1912 and in most cases mortality of balsam fir has been severe.

The insect overwinters as an egg. There are four larval instars, the duration of the larval period averaging 49 days. Feeding experiments showed that young larvae could be reared successfully from the egg on new foliage of balsam fir or white spruce or on leaves of birch or maple. Unacceptable diets were 'old' spruce or balsam foliage, moss, or leaves of alder, mountain ash, raspberry, or bunchberry. In the third and fourth instars old foliage of spruce or balsam fir was acceptable.

A photopositive reaction enables larvae to reach new foliage at the branch tips, while a photonegative reaction in the post-feeding stage causes them to seek darkened pupation sites.

The pupal period averaged 22 days. The adult life-span averaged 14.3 days for females and 9.4 for males. Of the adults reared 55 per cent were females and 45 per cent were males. Eggs are laid singly on sites ranging from moss on the forest floor to lichens on the tree.

A larval disease has been an important factor in terminating several outbreaks. The two most common parasites reared have been *Aoplus velox* (Cress.) and *Apanteles* sp. nr. *flavovariatus* (Mues.).

Outbreaks have occurred in mature or overmature stands of balsam fir and an increase in the spruce content of a stand seems to result in a corresponding decrease in susceptibility to attack.

Acknowledgments

The study was initiated as a Forest Insect Survey project by R. E. Balch and W. A. Reeks of the Forest Biology Laboratory, Fredericton, N.B., and their criticisms have been most helpful. Acknowledgment is also made of the assistance given by W. C. Parrott, both in field studies and in the preparation of the map and graphs. Thanks are due the following specialists of the Systematic Unit, Division of Entomology, Ottawa: E. G. Munroe, for confirming identification of the adult looper; O. Peck, R. M. Mason, G. S. Walley, and G. E. Shewell for identifying parasite material.

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Insects Affecting Seed Production in Red Pine
Part I *Conophthorus resinosae* Hopk. (Coleoptera: Scolytidae)[1]

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Introduction

Natural and artificial reforestation, which basically depend on an abundance of sound seed, are adversely affected when insects destroy large numbers of cones, seeds, and cone-bearing shoots. Other factors, such as unfavourable weather, incomplete seed development, and damage by birds and mammals also reduce seed production, but they are rarely of such widespread importance as insects, whose damage often results in the failure of seed crops over large areas. Cone and seed insects sometimes restrict the natural regeneration of trees for a few years at a time, as, for example, in conifers on the Pacific coast (16), loblolly pines in Virginia (13), and oak in Michigan (5), but they become particularly important when the seeds they destroy are required for use in artificial reforestation. The future success of much reforestation, which is inclining more and more toward the use of seed obtained from trees cultivated especially for that purpose, may largely depend on a thorough understanding of cone and seed insects and their effect on seed production.

Insect damage to cones of red pine, *Pinus resinosa* Ait., in Ontario is extremely variable from place to place and from year to year, but is often severe enough to make commercial seed collecting impossible or uneconomical. This variability is partly due to the relative abundance of different insects, some of which are more destructive than others, and partly to fluctuations in cone production. As a general rule, a sudden large increase in cone production tends to "outdistance" the ensuing increase in insect damage, with the result that many cones and seeds escape uninjured. Conversely, sharp decreases in cone production concentrate the insects in fewer cones than had previously been available, with the result that damage is relatively more severe. However, decreases in cone production also lead to competition between insects that seek the same food and shelter, and are thereby important in the natural control of the insects.

Damage by insects to red pine cones in Ontario is very similar to that in many other North American pines. Almost all seed loss occurs during the second (final) year of cone development, and is caused by insects that tunnel through the cone. First-year cones succumb when the supporting shoot is

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killed, but this loss is seldom appreciable. The cone beetle, *Conophthorus resinosae* Hopk., is especially destructive in red pine, as are other species of this genus in other pines, e.g. *C. coniperda* (Schz.) in eastern white pine, *Pinus strobus* L. (4), *C. edulis* Hopk. in pinyon, *P. edulis* Engelm. (14), *C. ponderosae* Hopk. in ponderosa pine, *P. ponderosa* Laws. (16, 17), and *C. lambertianae* Hopk., in sugar pine, *P. lambertiana* Dougl. (16, 17). Similarly, other red pine cone insects, *Dioryctria* spp., *Eucosma monitorana* Hein., *Laspeyresia toreuta* Grt., and *Rubsaamenia* sp., or their close relatives, attack the cones of other pines. Circulionids, buprestids, cerambycids, and seed chalcids, all of which have been reported from the cones of other pines, were not found in red pine cones during this study.

The first three parts of this series are devoted to the biology and natural control of the insects that were found inhabiting red pine cones in central and southern Ontario during the period 1950 to 1954. These insects are dealt with approximately in order of their importance, beginning with *C. resinosae* in the remainder of the present paper, continuing with *Dioryctria* spp. in Part II, and with *Eucosma monitorana*, *Laspeyresia toreuta*, *Rubsaamenia* sp., and other insects in Part III. Part IV of the series will deal with the time, duration, extent, and recognition of cone damage.

Apart from *C. resinosae* and *Rubsaamenia* sp., which were identified respectively by Dr. W. H. Anderson and Dr. R. H. Foote, United States National Museum, Washington, D.C., all the insects discussed in this series were identified by officers of the Insect Systematics and Biological Control Unit, Entomology Division, Science Service, Department of Agriculture, Ottawa.

Conophthorus resinosae Hopk.

The genus *Conophthorus* was erected in 1915 by A. D. Hopkins (10) to accommodate 15 species of beetles inhabiting cones and twigs of the genus *Pinus* in North America. Before Hopkins' description of *C. resinosae*, the red pine cone beetle had been variously referred to as *Dryocoetes affaber* Mann. (18), *Dryocoetes septentrionalis* Mann. (8), *Dryocoetes* sp. (7), and *Pityophthorus coniperda* Schz. (20). There have been no additions to, or revisions of, the genus *Conophthorus* since Hopkins' paper.

Several species of *Conophthorus* are economically important, but few have been intensively studied. Miller's study of Pacific coast cone insects (16, 17) deals with *C. ponderosae* Hopk. and *C. lambertianae* Hopk., while Little (14) gives a short description of the activity of *C. edulis* Hopk. in piñon cones. Cone beetles receive only passing attention in general treatises on forest insects, although Miller's report is quoted extensively by Chamberlin (3). Craighead (4) describes damage by cone beetles, emphasizing seed losses in white pine owing to *C. coniperda* (Schz.). Some information on the importance and habits of *C. resinosae* in Ontario, arising from the present study, has already been mentioned briefly (15).

In Ontario, *C. resinosae* has been encountered in greatest numbers within the triangular area defined by Sault Ste. Marie, Ottawa, and Lake Simcoe. The Forest Insect Survey, Forest Biology Division, Department of Agriculture, Ottawa, also records *C. resinosae* from Nova Scotia and Quebec. According to Dr. W. H. Anderson, *C. resinosae* specimens in the United States National Museum are from New Hampshire, New York, Michigan, Minnesota, and Wisconsin. Hopkins (10) lists *C. resinosae* from Maine and Ontario.

Although second-year red pine cones are the preferred host of *C. resinosae*, broods frequently develop in current-year's red pine shoots, and occasionally

Fig. 1. Egg, second-instar larva, pupa, and adult of *Conophthorus resinosae* Hopk.

in second-year cones of jack pine (*Pinus banksiana* Lamb.). However, the behaviour of the beetle in these hosts is very similar to, if not identical with, that in red pine cones.

Description of Developmental Stages

Egg

Recently deposited eggs are ovoid, pearl-white, translucent, and thin-walled (Fig. 1). Preserved eggs are 0.86-1.02 mm. long and 0.53-0.79 mm. wide. The head capsule of the first-instar larva is visible shortly before hatching.

Larva

The typically scolytid larva is apodous, soft-bodied, and white, with a light brown head (Fig. 1). The head-width measurements of a representative group of larvae of all ages clearly fall into two separate frequency distributions (Fig. 2), indicating that *C. resinosae* has only two larval instars; the identity of the first was established by measurements of larvae that were still within the egg. Assuming that larvae with heads wider than 0.49 mm. included in Fig. 2 belong to the second instar, the mean head width of the two instars is 0.42 ± 0.003 mm. and 0.61 ± 0.003 mm., respectively. The presence of only two larval stages does not seem to have been reported for any other scolytid, although number of instars within the family is variable, e.g. three in *Ips pini* (Say) and *Pityokteines sparsus*

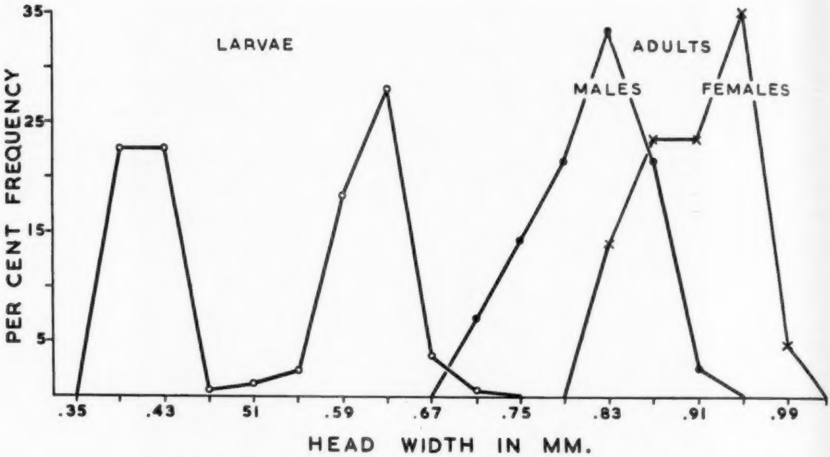


Fig. 2. *Conophthorus resinosae* Hopk. head width frequency distributions. (Based on 164 larvae and 84 adults).

(Lec.) (19), four in *Dendroctonus simplex* Lec. (19), five in *Pityogenes hopkinsi* Swaine (2) and *Dendroctonus pseudotsugae* Hopk. (1), either five or six in *Hylurgopinus rufipes* (Eichhoff) (11), and seven in *Scolytus ventralis* Lec. (21).

Pupa

The pupa (Fig. 1) is white when newly formed, and darkens first on the mandibles, eyes, and ends of the elytra.

Adult

The mature adult of *C. resinosae* (Fig. 1) is a shiny, black, cylindrically-shaped beetle with sparse pubescence and an unsculptured elytral declivity. The head, which cannot be seen from above, is retractable within the pronotum. The length of 15 beetles collected from cones at Sault Ste. Marie varied from 3.00 to 3.46 mm., averaging 3.24 mm. Females are generally larger than males. Head-width distributions of the two sexes are plotted in Fig. 2. The mean head width of males is 0.80 ± 0.008 mm., and of females, 0.91 ± 0.007 mm. No obvious secondary sexual characters were found that enable easy diagnosis of sex. However, if living beetles are immersed in water and examined under the microscope, a small median sclerotized bar underlying the egg tube can be seen in the female. There is no such bar in the male, but the copulatory apparatus is sometimes visible through the genital opening. The sexes are apparently about equal in number.

Seasonal History

Cone Attack and Oviposition

Seasonal activity of *C. resinosae* begins in May when the beetles leave their overwintering quarters and attack the current-year's shoots and second-year cones of red pine. During the first few weeks the beetles feed individually and do not mate or oviposit. Cone attack for oviposition usually begins in late May, but was observed to begin as early as mid-May and as late as mid-June, depending on the year and locality. The cone is attacked first by the female, and sometimes only by the female. Initial penetration occurs very close to the petiole on the underside of the cone, which usually projects horizontally from the branch. The entrance tunnel is usually completely enclosed, but occasionally

forms an open groove at the cone base. When the beetle reaches the centre of the axis, it turns and bores distally, constructing evenly spaced blind egg niches downward into the cone substance. As soon as a niche has been dug, the female deposits an egg in it and fills the niche with debris flush with the tunnel wall before extending the tunnel. The axial tunnel, with egg niches (Fig. 3), is gradually extended to the end of the cone axis, the length of which apparently limits the number of eggs that can be laid; egg number varies from one or two in the smallest cones to 10 or 11 in the largest. After oviposition has been completed the female returns to the base of the cone via the axial tunnel, which has been kept free of debris, and before leaving the cone, fills the base of the tunnel with a plug of resin and debris. This plug at first is soft but later hardens.

It is noteworthy that the female performs all the important functions of cone attack, including initial penetration, construction and filling of egg niches, and plugging of the axial tunnel. The male is usually, but not always, present during cone attack, but contributes nothing to the work. Cones attacked by unaccompanied females contain viable eggs, and differ from cones containing both males and females only by lacking a widening at the base of the axial tunnel. This widening is either a turning niche or a nuptial chamber, or both.

In 1952, a pair of beetles was observed in a freshly attacked cone that had been sectioned to expose the axial tunnel. While the female excavated an egg niche near the distal end of the cone, the male rested in the widening of the axial tunnel near the base, facing proximally. Mating occurred 12 times during 3.5 hours, always at the instigation of the male, but no eggs were laid during this period. The interval between matings varied from 10 to 32 minutes, during which the male occasionally dug shallowly in the wall of the tunnel. In this cone, mating took place in the axial tunnel near the egg niche under construction, but in an intact cone the narrowness of the tunnel might force the beetles to retreat to the widening of the axial tunnel near the cone base.

Although it is known that a female can attack several cones, the total egg output was not determined, since the female contains no more than four mature eggs at one time. However, in an experiment where adults were permitted to attack a number of cones, one female laid 17 eggs in four cones, while three others each attacked three cones, depositing 12, 15, and 22 eggs, respectively. The interval between consecutive cone attacks varied from two to 16 days, with a mean interval of about 7.5 days.

The striking differences in the method of cone attack by different *Conophthorus* species are possibly related to differences in cone structure of the various species of pine. In cones with a long petiole, the beetle enters through a tunnel started in the petiole, e.g. *C. lambertianae* in sugar pine (17), and often *C. coniperda* in white pine cones. In cones with a very short petiole, the beetle tends to enter directly at the base, e.g. *C. ponderosae* in ponderosa pine (17), *C. contortae* in lodgepole pine (3), and *C. resinosae* in red pine. However, according to Little (14), *C. edulis* enters the sessile piñon cone "by boring into the stalk at the base". Although *C. resinosae* and *C. ponderosae* both attack sessile cones, the behaviour of the two species inside the cone differs considerably. According to Miller (17), after initial penetration of the cone, the adult *C. ponderosae* does not immediately tunnel along the cone axis, but ". . . . . bores completely around the axis, forming a short spiral tunnel. This spiral twist . . . is characteristic of attack in yellow pine. Its result is completely to cut off nourishment and ensure deadening of the cone, which produces the condition necessary for the development of the larvae." Cones of *Pinus ponderosa* are

two to four times as large as those of *P. resinosa*, and the spiral tunnel of *C. ponderosae* may be a specialization to ensure the death of the cone.

The manner of exit of parent beetles from the cone is also variable within the genus *Conophthorus*. *C. resinosae* adults leave the red pine cone via the entrance tunnel, as previously described. Miller (17) shows photographs of the *C. ponderosae* tunnel in ponderosa pine cones, in which it seems that the parent adults of this species also leave via the entrance tunnel, but this is not stated specifically in the text. After completion of attack in cones of sugar pine and white pine, respectively, adults of *C. lambertianae* and *C. coniperda* bore out through the distal end of the cone (17, 23). In contrast to *C. resinosae*, which keeps the axial tunnel clear of debris, *C. coniperda* permits the tunnel to remain congested with gum and frass.

Soon after attack by *C. resinosae*, the red pine cone begins to wither and discolour, and eventually turns hard and brown. The attachment to the branch becomes weakened, and if the cone falls from the tree, as occasionally happens, the remaining grooved stub (Fig. 4) is indicative of *C. resinosae* injury.

Larval Development

Within the cone, the larvae feed more or less indiscriminately on seeds and scales, without tunnelling in any particular direction, and pupate in frass-lined cells, often near the cone base (Fig. 5). The dead cone begins to disintegrate during the year after attack, owing partly to natural decay and partly to the activity of secondary insects.

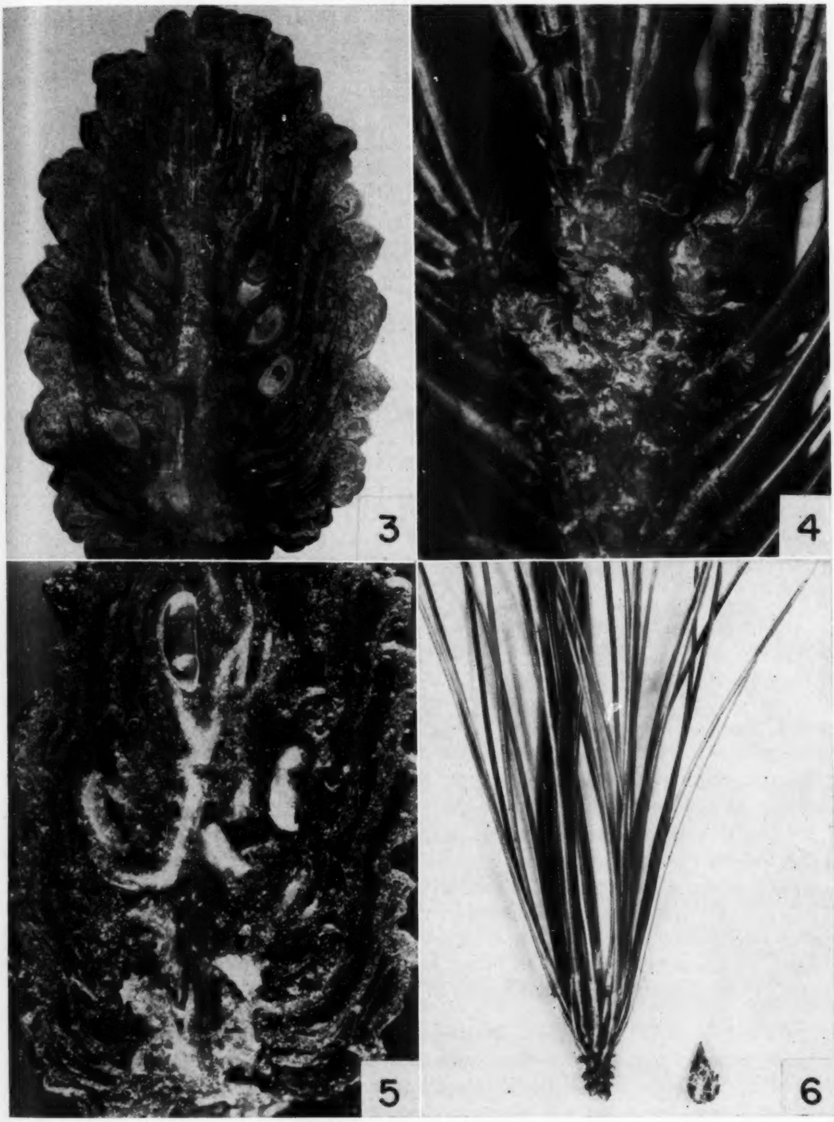
At Sault Ste. Marie in 1951, the seasonal development of a *C. resinosae* population in infested cones was followed throughout the summer by frequent sampling. There was considerable overlapping of successive immature stages, and ovipositing adults persisted until at least mid-July, only a few days before the first appearance of adult offspring. The duration of the immature stages, estimated by the interval between peaks of successive stages, was: egg, 17 days; instar I, 13 days; instar II, 22 days; pupa, 19 days.

Adult Emergence

New adults remain inside the dead cone at least until they become hard and black. Most leave through the plug in the axial tunnel, but some bore out through the top or sides of the cone. The period between the first appearance of adults and the beginning of emergence from the cone was 12-13 days at Sault Ste. Marie in 1951. In 1952 at Chalk River it was noticed that emergence of adults from cones in rearing cages lagged considerably behind that from cones under natural conditions, and that the air temperature around cones in rearing cages was usually lower than in the open, suggesting that temperature was influencing adult emergence. A study of adult emergence and cone temperature revealed that at cone temperatures below about 22°C. emergence was retarded, but that between 22 and 43°C., the highest temperature recorded, emergence increased with increasing temperature. During this study it was noticed that adult beetles tended to move to the light at low temperatures but to shade at higher ones, suggesting that reaction to light is affected by temperature. Tests in a light-choice chamber designed by Green (6) showed that this was indeed so and that the 50 per cent reversal point occurred at about 27.5°C. The light reversal reaction serves to protect *C. resinosae* adults from high lethal temperatures by causing them to seek shade and, hence, cooler conditions.

Adult Overwintering

Shortly after leaving the cone in late summer, the adult prepares for winter by entering a short, current year's red pine shoot and tunnelling distally through



Figs. 3-6. 3, Median longitudinal section through a second-year red pine cone attacked by *Conophthorus resinosae* Hopk. (Note: entrance tunnel at base from right, axial tunnel slightly to right of cone axis, egg niches off axial tunnel). 4, Broken stalks of second-year red pine cones killed by *Conophthorus resinosae* Hopk. (Note the transverse groove at the end of the stalk made by the beetle on entering the cone.) 5, Section of a dead second-year red pine cone containing an adult and two pupae of *Conophthorus resinosae* Hopk. 6, Broken twig and detached vegetative bud of red pine, mined by adult *Conophthorus resinosae* Hopk. in late summer.

TABLE 1
Distribution of Twig Damage by *C. resinosae* on Lower Branches of 25-year-old Open-Grown Red Pines. Midhurst, 1953.

Distance from trunk (in.)	Number of suitable twigs	Per cent of twigs attacked
0–20	60	15.0
21–40	141	12.0
41–60	323	10.2
61–80	214	7.0
81–100	222	6.3
101–120	142	3.5
121–140	77	1.3
141–160	15	0

the pith into the vegetative bud. The twig is weakened at the point of entry and soon breaks off and falls to the ground (Fig. 6). White pine twigs are also occasionally attacked. No adults were found overwintering in dead cones, although Keen (12) states that these are the usual overwintering quarters for *Conophthorus* beetles. However, Struble (22) has shown that some *C. lambertianae* adults leave dead sugar pine cones in late summer and tunnel in twigs. In contrast to adults of *C. resinosae,* those of *C. lambertianae* tunnel proximally from behind the vegetative bud and abandon the twigs before the onset of winter.

The location of twig damage in relation to the distribution of suitable twigs (ones not bearing ovulate cones) was recorded on the lower branches of 25-year-old open-grown red pines at Midhurst in 1953. Table I shows the frequency distribution of 1194 suitable twigs according to their distance from the tree trunk, and the intensity of twig damage within the same distance classes. Twig damage was heaviest close to the trunk and decreased gradually outward, suggesting that higher temperatures at the periphery of the tree crown may have influenced the beetles to seek the inner, shaded portions.

The phenomenon of extended dormancy which has been reported for some cone insects (16, 24), does not occur in *C. ponderosae* and *C. lambertianae* (17), or in *C. resinosae*, although Chamberlin (3) states that some *Conophthorus* species ". . . . . may even pass two winters in the cone in which they developed". Delayed emergence in *C. resinosae* would probably have no survival value, however, owing to this insect's ability to breed in other parts of the tree and in other host trees in the absence of second-year red pine cones.

Natural Control

A detailed account of the cause and extent of mortality throughout the life of *C. resinosae* would be of great interest, since this information, combined with estimates of expected cone production, might permit the forecasting of population trends and seed losses. However, owing to the limitations of the investigation, no such complete account of mortality can be given here, and it is only possible to outline the more obvious factors contributing to mortality and to assess the effectiveness of each factor on the basis of experience and the available evidence.

Parasitism and disease, although important in some *Conophthorus* species (9, 17) were found negligible in *C. resinosae*. During the present investigation, no mortality of the insect in cones could be attributed to parasitism or disease, although two adults of *Bracon rhyacioniae* (Mues.) (Hymenoptera: Braconidae)

were recovered from larvae feeding in current-year's shoots. Most of the mortality encountered was due to predation by and competition with, other insects, and high temperature.

Larvae of a beetle tentatively identified as *Attalus nigrellus* (Lec.) (Coleoptera: Melyridae) were found to prey on *C. resinosae* larvae, pupae, and immature adults. They killed pupae and adults most often by attacking on the ventral side of the abdomen. The red, dorso-ventrally flattened larvae overwinter in infested cones, and transform the following spring into black, brachelytrous, soft-bodied adults about 4 mm. long. Predation by *A. nigrellus* was light in most localities, but caused 32% mortality at Chalk River in 1952.

Several lepidopterous species, including *Holcocera immaculella* McD. (Blastobasidae), *Duvita vittella* Bsk. (Gelechiidae), and *Recurvaria* sp. (Gelechiidae), fed in deteriorating cones, and occasionally preyed upon *C. resinosae* larvae and pupae. Predation by *H. immaculella* larvae seemed to be most effective in small cones. Reddish-orange, cylindrical maggots of *Lestodiplosis* sp. (Diptera: Cecidomyiidae) were found preying on *C. resinosae* larvae at Midhurst and Sault Ste. Marie in 1954.

In some localities, many *C. resinosae* larvae succumbed in competition with another primary cone insect, *Eucosma monitorana* Hein. On open-grown trees near Alice in 1952, about 60% of the cones infested with *C. resinosae* were also fed upon by *E. monitorana* larvae. Mortality of *C. resinosae* was calculated to be about 97% in dually infested cones, but only about 18% in cones where it occurred alone.

Some mortality of immature stages of *C. resinosae* in cones could not be attributed to other insects. At Sault Ste. Marie in 1951, mortality due to unknown factors reached 12% and was greatest in small cones. High temperature possibly accounted for many of the dead adults that were commonly found in cones. During the previously described experiment on the relation between temperature and adult emergence, beetle mortality in cones exposed to direct sunlight amounted to as much as 20%, but was nil in shaded cones. Mortality among overwintering beetles is probably slight, but in one sample was found to be significantly greater in buds with staminate flower primordia than in those without (15% compared to 3%, Sault Ste. Marie, 1951).

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Notes on *Coenosia tigrina* (F.) (Diptera: Anthomyiidae), Mainly on Habits and Rearing[1]

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Coenosia tigrina (F.) was first observed in Canada in 1943 at Ottawa by Mr. A. R. Brooks of the Entomology Division (Mr. G. E. Shewell, Entomology Division, Ottawa, personal communication). By 1947 the insect had been collected as far west as Guelph, Ontario. It was first recorded from the province of Quebec in 1951 by Perron and Lafrance (1952), who observed it preying on adults of *Hylemya antiqua* (Mg.) in rearing cages at St. Jean. Later observations and surveys by these workers indicated the predator to be very abundant in southwestern Quebec. More recently Mr. F. M. Cannon (personal communication), Field Crop Insect Section, Science Service Laboratory, Charlottetown, Prince Edward Island, and Mr. L. A. Miller (personal communication), Entomology Laboratory, Chatham, Ont., reported *C. tigrina* to be present as far east as Charlottetown and as far west as Chatham.

According to Dr. Mary Miles (personal communication), Wye College, University of London, England, the species is apparently well known in Europe

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Fig. 1. Newly emerged adult of *C. tigrina* with pupal case.
Fig. 2. *C. tigrina* adult feeding on *H. antiqua* adult.

as a predator of adult Diptera but is not common in England as she has observed it only once in several years while studying *H. cilicrura* (Rond.).

As *C. tigrina* adults are often found associated with *H. antiqua* adults, the following brief comparison of the major differences in characters of these two species is given to permit ready identification in the field.

The adult is approximately the size of the onion maggot adult but can be fairly easily distinguished from it by its greyish colour and the four black dots on the dorsal part of the abdomen (Fig. 1). On the average it is of a slightly darker shade of grey than *H. antiqua.* The following are the most obvious differences between *C. tigrina* and *H. antiqua* adults.

H. antiqua (Mg.)	*C. tigrina* (F.)
Eyes of male almost meeting above	Eyes of male widely separated
Frons of female half as wide as head	Frons of both sexes one-third as wide as head
Arista pubescent	Arista plumose
Abdomen unspotted	Second and third abdominal segments each with a pair of black spots
Femora black	Femora reddish-yellow on apical third
Tibiae black	Tibiae reddish-yellow
Hind tarsus longer than hind tibia	Hind tarsus shorter than hind tibia
Claws and pulvilli of female not more than half as long as last tarsal segment	Claws and pulvilli of both sexes longer than last tarsal segment

The fact that both the immature and adult stages of *C. tigrina* are predacious makes it the most important known dipterous predator of root maggots in southwestern Quebec.

Habits

The adults of *C. tigrina* are usually observed in the field in southwestern Quebec from early May to late October. The number of generations is not

known but the period of activity of this predator corresponds to that of *H. antiqua*. In the early spring, *C. tigrina* adults may be found inside hotbeds feeding on small flies that gather in these places when the weather is cool. During the summer and early fall they are commonly seen in the field resting on weeds or on cultivated plants where other Diptera are present. They ordinarily attack flies of their own size or smaller. Small Hemiptera were also observed to be attacked by this predator.

C. tigrina attacks its prey in flight or at rest, holds it firmly between its legs, pierces it between the head and the thorax, and sucks the blood from that part of the body. Very often it pierces the fly's abdomen and continues to feed for some time. The prey appears to die very shortly after being attacked, but the feeding continues for 10 to 15 minutes. Frequently the predator, when disturbed, flies with the prey to another resting place.

In the insectary during the summer, recently emerged adults of *C. tigrina* killed an average of five *H. antiqua* adults per day. As they grew older they killed only one or two per day. In rearing cages when prey were scarce, *C. tigrina* resorted to cannibalism.

In the insectary, adults of *C. tigrina* in copula generally rest on solid objects and remain in copula for several minutes. The preoviposition period averaged 15 days, varying from eight to 18 days.

From 20 to 25 eggs may be laid in one day by a field-captured female. They are laid at random on or just beneath the surface of the soil and are found from late May to late October. Most of them are laid early in the life of the female and are usually deposited singly. Very rarely are there more than three eggs laid close together. Because of their colour and the indiscriminate way they are laid, with no relation to bare ground or vegetation, they are difficult to find in the field. Fertilized eggs have a high degree of hatchability. Eighty-five per cent of the eggs laid by field-captured females hatched from three to eight days after oviposition.

Rearing

As rearing *C. tigrina* was necessary in a study of the immature stages and as a review of the literature revealed no adequate laboratory method, a method was devised.

Eggs were obtained from *C. tigrina* adults captured in the field, caged, and fed house flies, pomace flies, and onion maggot adults.

Attempts to rear the larvae on roots of lettuce, dandelion, couch grass, and plantain and on onion bulbs, potato tubers, well-decomposed vegetable matter, horse manure, and milk and cellucotton were unsuccessful. A small number of larvae were kept alive seven to eight days when fed live, punctured larvae of *H. antiqua*, but did not survive beyond this stage.

The larvae were finally reared by feeding them freshly formed pupae of *H. antiqua*, the puparia being cut open at one end with sharp scissors so that the opening allowed the larvae ready access to the prey. Each larva was placed with its prey between two sheets of water-soaked No. 2 Whatman filter paper in a petri dish, and fed one pupa per day up to the fifth day. From the fifth day until the pupal stage, each larva was fed two pupae daily. The larvae accepted only newly formed, freshly opened pupae and refused those of more advanced development or opened for more than several hours. All the larvae reared in this way developed into healthy pupae, from which emerged well-formed, vigorous adults.

At room temperature in the laboratory, development of the larva from hatching to maturity required about 12 to 14 days. The pre-pupal stage took approximately one to two days, and the pupal stage approximately 15.

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Sixth Annual Meeting of the Entomological Society of Canada

The sixth annual meeting of the Entomological Society of Canada was restricted to a business session on the eve of the Tenth International Congress of Entomology and was held in the Medical Building, McGill University, on August 16 at 8 p.m. About 65 members attended. The President, Rev. O. Fournier, was in the chair. Two meetings were held, the first being of the unincorporated society and the second of the incorporated one.

At the meeting of the unincorporated society, on motion of A. A. Beaulieu and G. A. Moore, incorporation was ratified as approved in principle at the annual business meeting in 1955 and resolved by the Board of the unincorporated society on March 2, 1956.

At the meeting of the incorporated society, on motion of A. D. Pickett and C. L. Neilson the minutes of the meeting of the first directors and also of that of the Directors of the incorporated society at Ottawa on March 2, 1956, were approved. These concerned transfer of the members and of all Society affairs to the incorporated society, adoption of the by-laws (constitution), and resolutions of the Board of Directors detailing the methods of operation of the Society on the basis of the by-laws. Approval of the minutes concluded the business of incorporation.

The Treasurer, B. M. McGugan, supplied copies of the audited financial report for 1955 and gave an interim report for January 1 to August 1, 1956. The revenue for the calendar year 1955 totalled $13,401.23 and the disbursements $13,466.42. The accounts receivable were estimated at $2,647.34 and the accounts payable at $2,653.44, giving a deficit of $71.29. However, $332 had been received for back numbers on a long-overdue account, $334 had been refunded on sales taxes on reprints, and the Society had contributed $1,000 to the Tenth International Congress of Entomology, so that, apart from these three items, there was a small surplus. The mailing list for *The Canadian Entomologist* at December 31 was made up as follows: regular members, 514; honorary and life members, 13; subscribers, 300; exchanges, 98; advertisers, 6; total, 931. The total at December 31, 1954, was 880. The interim report showed that the revenue and expenditures to August 1 totalled $6,738.76 and $5,817.70 respectively and the accounts receivable and the accounts payable $936.80 and $785.42 respectively.

The Editor, W. R. Thompson, reported that in the 11 months since the previous meeting 71 papers by 93 authors, totalling 634 pages, had been published. The two supplements by E. C. Becker and B. P. Beirne were in page proof; another supplement, "The New World Species of *Chrysomela*", by W. J. Brown, was in galley proof.

The Secretary reported that the new constitution, as approved at the annual meeting in 1955, was mailed to all members on April 10, 1956, and that the results of the first election of officers by mail ballot, 288 ballots having been cast by a total of 410 members in good standing, were as follows:—President, 1956-57,

R. Glen; President-elect, 1956-57, G. P. Holland; directors at large, 1956-58, M. L. Prebble, J. G. Rempel; directors at large, 1956-57, Mrs. J. B. Adams, W. A. Reeks, W. R. Thompson; directors representing regional entomological societies, 1956-58, F. M. Cannon, R. H. Ozburn, L. G. Putnam, H. Andison; 1956-57, J. A. Duncan, G. L. Warren, C. W. Farstad.

The Chairman of the Committee on Common Names of Insects, A. V. Mitchener, reported that 15 of the 19 names submitted during the year had been approved by the committee and forwarded to the committee of the Entomological Society of America. It was approved that there be one member at large on the Committee, in addition to one representing each of the regional societies and the Insect Systematics and Biological Control Unit of the Entomology Division.

The Convener of the Membership Committee, R. E. Balch, submitted forms for application for membership in the Society and for nominating honorary members, proposed various duties for the committee, and recommended that a student class of membership be provided. It was agreed to refer the report to the Board, for report to the next annual business meeting concerning the recommended change in the constitution (a vote by mail ballot then being necessary to allow student membership).

W. S. McLeod and W. A. Fowler were appointed auditors for the 1956 accounts.

The President-elect, R. Glen, appointed committees as follows:—Nominating Committee: B. N. Smallman (convener), B. Hocking, E. J. LeRoux; Election Committee: E. B. Watson (convener), C. D. F. Miller, L. L. Reed; Membership Committee: W. A. Reeks (convener), the two others to be selected by the convener from the vicinity of Winnipeg.

The annual meeting of the Society in 1957 will be held jointly with that of the Entomological Society of Alberta at Lethbridge from October 29 to 31.

On taking the chair as President, R. Glen extended to Rev. O. Fournier the great appreciation of the Society for his services during his term of office.

R. H. Wigmore, *Secretary*

Entomological Society of Ontario

Prospective authors and contributors are asked to note that the final date for submission of material for inclusion in the Annual Report, Vol. 87 (1956) has been set by the Editor as February 28th, 1957. Mail material to the Editor, Annual Report, Entomological Society of Ontario, Department of Entomology, Ontario Agricultural College, Guelph, Ontario. Please conform with directions on back page of Vol. 86.

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